Final Draft

BASELINE ECOLOGICAL RISK ASSESSMENT

Upper Animas Mining District

San Juan County, COLORADO

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LIST OF ABBREVIATIONS AND ACRONYMS

Ag	silver
Al	aluminum
As	arsenic
AUF	area use factor
BAV	bioavailability
BBridge	Bakers Bridge
BERA	baseline ecological risk assessment
Be	beryllium
BCF	bioconcentration factor
BLM	Bureau of Land Management
BW	body weight
CCC	criteria continuous concentration
Cd	cadmium
CDOW	Colorado Division of Wildlife
CDPHE	Colorado Department of Public Health and the Environment
CO	Colorado
COPEC	contaminant of potential ecological concern
Cr	chromium
CSM	conceptual site model
CTE	central tendency exposure
Cu	copper
DL	detection limit
DW	dry weight
EDD	estimated daily dose
EPA	United States Environmental Protection Agency
EPC	exposure point concentration
ER-L	effect range-low
ER-M	effect Range-Median
EU	exposure unit
Fe	iron
FIR	food ingestion rate
ft	feet
gpm	gallons per minute
HBI	Hilsenhoff Biotic Index
HQ	hazard quotient
HRW	hard reconstituted water
LEL	lowest effect level
LOE	line of evidence
mg/kg	milligrams per kilogram (parts per million)
mg/kg.d	milligrams per kilogram per day
mg/kg bw.d	milligrams per kilogram body weight per day
MMI	Mobile Metal Ions
Mn	manganese
Ni	nickel

NRWQC	national recommended water quality criteria
Pb	lead
PEC	probable effect concentration
PEL	probable effect level
RME	reasonable maximum exposure
ROC	receptor of concern
Se	selenium
SEL	severe effect level
SGC	Sunnyside Gold Corporation
Site	mainstem Cement Creek, mainstem Mineral Creek, and the Animas River at and below Silverton
SLERA	screening-level ecological risk assessment
SMAV	Species Mean Acute Value
SSL	soil screening level
T&E	threatened and endangered
TEC	threshold effect concentration
TEL	threshold effect level
TRV	toxicity reference value
UCL	Upper Confidence Limit
WIR	water ingestion rate
WP	work plan
WQC	water quality criteria
Zn	zinc

EXECUTIVE SUMMARY

ES.1 Introduction

The Animas River flows through the town of Silverton in San Juan County, CO. This waterway is affected by flow which has come in contact with mineralized material, either naturally or as a result of mining activities, such as through the creation of mine adits. Affected water originates in the upper reaches of the two major tributaries of the Animas River in this area, namely Cement Creek and Mineral Creek, and from other tributaries of the Animas River further upstream of Silverton. The tributaries contain high levels of metals and acidity that are carried downstream to the Animas River. This evaluation did not attempt to separate natural contamination from past mining-related contamination, but assessed the total risk from all sources combined.

The Exposure Units (EUs) evaluated in this Baseline Ecological Risk Assessment (BERA) consist of the following water bodies:

- *The Animas River above mainstem Cement Creek*: this reach of the Animas River covers about two river-miles between sampling locations A60 and A68. All the sampling locations from this reach of the river were combined into a single EU. Location A68 is the furthest downstream in this reach and is located about 1,000 feet (ft) above the confluence with mainstem Cement Creek. Location A56, situated about 1,000 ft above A60 and just upgradient of the Mayflower Mill and the Arrastra Creek, represents regional "upstream" conditions. Note that this BERA did not consider this location to represent reference conditions because both the surface water and sediment samples collected at A56 carry a persistent contaminant signal which appears to be associated with mining or ore-related sources further upstream in the watershed.

- *The Animas River between mainstem Cement Creek and mainstem Mineral Creek*: this reach of the Animas River covers about one river-mile between the confluences of the two creeks. Location A69A is about 3,000 ft downstream of the confluence with mainstem Cement Creek (just upstream of Idaho Gulch), whereas location A70B is just upstream of the confluence with mainstem Mineral Creek. Both of these sampling locations are combined into one EU.

- *The Animas River below mainstem Mineral Creek*: this reach of the Animas River covers about 30 river-miles between sampling locations A71B, and Bakers Bridge (BBridge). The following values represent the approximate distance (in river-miles, where appropriate) separating the point where mainstem Mineral Creek enters the Animas River in Silverton and the downstream sampling locations: A71B—around 300 ft, A72—around 3,500 ft, A73/A73B—5.9 miles, A75D/A75B—18.9 miles, and BBridge—30 miles. Each sampling location on this reach of the river is considered as a distinct EU due to the large distances separating A71B and BBridge.

- *Mainstem Cement Creek*: the section evaluated in this BERA is represented by sampling locations CC48 and CC49 found on the creek within one mile of the confluence with the Animas River. Both sampling locations are combined into one EU.

- *Mainstem Mineral Creek*: the section evaluated in this BERA is represented by sampling location M34 found on the creek just upstream of the confluence with the Animas River.

The main goal of this BERA is to refine the risk estimates presented in the Screening-Level Ecological Risk Assessment (SLERA; TechLaw, 2013) for different types of receptor groups, as follows:

- benthic invertebrates exposed to sediment in mainstem Cement Creek, mainstem Mineral Creek, the Animas River above Cement Creek, and the Animas River below Mineral Creek (note: no sediment samples were collected from the Animas River between mainstem Cement Creek and mainstem Mineral Creek);

- benthic invertebrates exposed to pore water collected from undisturbed bedded sediment in the Animas River;

- fish exposed to surface water in mainstem Cement Creek, mainstem Mineral Creek, and the three reaches of the Animas River; and

- four wildlife species representing different trophic levels exposed via ingestion of surface water, sediment, and food items from the Animas River above mainstem Cement Creek and below mainstem Mineral Creek.

The analytes of interest to this BERA consist of Aluminum (Al), Arsenic (As), Beryllium (Be), Cadmium (Cd), Chromium (Cr), Copper (Cu), Iron (Fe), Lead (Pb), Manganese (Mn), Nickel (Ni), Selenium (Se), Silver (Ag), and Zinc (Zn). These metals are the Contaminants of Potential Ecological Concern (COPECs) investigated in the SLERA.

This BERA is a realistic evaluation to quantify risk to community and wildlife-level receptors exposed under current conditions. The evaluation recognizes that mainstem Mineral Creek upstream of the confluence with South Fork Mineral Creek, and mainstem Cement Creek, may not have supported viable fish or macroinvertebrate communities before large-scale mining activities started in the 19th century due to naturally high levels of metals and low pH levels in their surface waters. These two waterways are nonetheless included in this BERA to provide risk estimates and help identify risk drivers and exposure pathways of concern. It is expected that evaluating these waterways within a risk-based context will provide information to support a scientific management decision point for discussion among the stakeholders.

The surface water data represent dozens of samples collected from the five EUs between May 2009 and September 2014. The sediment data set is substantially smaller and consists of analytical data collected from those same waterways during five sampling events in May 2012, October 2012, May 2013, April 2014, and September 2014. The pore water data set consists of analytical data collected in April and September 2014. Samples obtained by the United States Environmental Protection Agency (EPA) and others before May 2009 as part of earlier investigations are not evaluated in this BERA in order to focus on "current" exposure conditions. The available information was reviewed to identify assessment endpoints and measures of effect, and to develop a Conceptual Site Model (CSM) which show the movement of contaminants from the sources to the receptors.

The effects evaluation uses chronic surface water benchmarks (hardness adjusted, if necessary), plus no-effect and effect sediment benchmarks, to quantify toxicity to aquatic community-level receptor groups exposed to surface water, sediment, and pore water. No-effect and effect Toxicity Reference Values (TRVs) for birds and mammals are used to assess the toxicity of metals via ingestion by wildlife receptors. In addition, surface water and sediment toxicity tests were performed in the laboratory on samples collected from mainstem Cement Creek, mainstem Mineral Creek, and the Animas River above Cement Creek and below Mineral Creek to measure effects to benthic invertebrates (the amphipod *Hyalella azteca*) and juvenile rainbow trout (*Oncorynchus mykiss*).

EPA and others assessed the benthic community structure and function in the five EUs and obtained benthic invertebrate samples for tissue residue analysis as part of additional sampling efforts performed in 2014 to enhance the existing database in support of this BERA.

The original surface water and sediment COPECs for benthic invertebrates and fish were re-selected in this BERA because more analytical data were generated since the SLERA was released in 2013. A metal detected at least once in sediment is retained for use in wildlife food chain modeling but only if it is also identified as an "Important Bioaccumulative Compound" in Table 4-2 of *Bioaccumulation testing and interpretation for the purpose of sediment quality assessment* (EPA, 2000).

Mainstem Cement Creek, mainstem Mineral Creek, and the three reaches of the Animas River are treated as separate EUs to derive Reasonable Maximum Exposure (RME) and Central Tendency Exposure (CTE) Exposure Point Concentrations (EPCs) for use in the baseline evaluation. The ProUCL software (EPA, 2013) was used whenever possible (depending on the size of the datasets) to calculate 95% Upper Confidence Levels (UCLs) for use as the RMEs and arithmetic means for use as CTEs. To fine tune the exposure to aquatic community-level receptors, the surface water data are further split into three hydrologic periods, namely the pre-runoff period (February to April), runoff period (May and June), and the post-runoff period (July to November). No surface water data are available for December or January.

The sediment data set is too sparse (five samples) to be split up into the three hydrologic periods. Instead, the sediment analytical data were combined across seasons for each EU to calculate RME and CTE EPCs for the sediment COPECs.

The EPC calculation method varied depending on the EUs, as follows:

- *Animas River above mainstem Cement Creek*: the surface water, sediment, and pore water analytical data were combined across the six sampling locations into separate datasets to calculate COPEC-specific RME and CTE EPCs for these three matrices. Also, a benthic invertebrate sample was collected from two sample locations in this reach for use in tissue residue analysis. These two samples were combined to calculate a mean and maximum tissue concentration for each COPEC for use in wildlife food chain modeling.

- *Animas River between Cement and Mineral Creeks*: only two surface water data points are available from the two sampling locations in this reach of the river. No sediment or benthic invertebrate samples were collected. Hence, wildlife receptors could not be evaluated because that would have required either (a) sediment analytical data to estimate the tissue residue levels in the food items for use in the food chain models, or (b) measured benthic invertebrate tissue residue data. The surface water analytical data were summarized by sampling location for calculating COPEC-specific RME and CTE EPCs to evaluate the fish community.

- *Animas River below mainstem Mineral Creek*: the various EUs in this lower reach of the river are separated by several hundred feet to several miles. As a result, the BERA assumes that wildlife receptors would not be exposed across this entire reach. Instead, the surface water, sediment, pore water, and benthic invertebrate analytical data are summarized by sampling location to calculate COPEC-specific RME and CTE EPCs for use in food chain modeling and to assess exposure to the benthic invertebrates and the fish community. Note that only one benthic invertebrate tissue sample was collected at each sampling location in the Animas River below mainstem Mineral Creek. Hence, the invertebrate tissue RME and CTE EPCs used in the food chain models were the same at each EU.

- *Mainstem Cement Creek*: this BERA does not evaluate wildlife receptors foraging in this EU because the SLERA showed that current chemical conditions in this waterway are too degraded to provide forage for wildlife. The surface water and sediment data from the two sampling locations at the mouth of the creek were used to calculate COPEC-specific RME and CTE EPCs to evaluate risk to the fish and benthic invertebrate community. No pore water samples were collected from this EU.

- *Mainstem Mineral Creek*: this BERA does not evaluate wildlife receptors foraging in this EU because current chemical conditions in this waterway are too degraded to provide

enough forage for wildlife. The surface water, sediment, and pore water data from the sampling location at the mouth of the creek were used to calculate COPEC-specific RME and CTE EPCs to evaluate risk to the fish and benthic invertebrate community.

Exposure to the four wildlife receptor species foraging in the reaches of the Animas River above mainstem Cement Creek and below mainstem Mineral Creek, is quantified using a food chain model which calculates RME and CTE Estimated Daily Doses (EDDs) based on ingesting surface water, sediment, and food items. The food items consist of benthic invertebrates (measured COPEC levels), fish (estimated COPEC levels based on sediment data), and aquatic plants (estimated COPEC levels based on sediment data), depending on the target wildlife species. Contaminant levels in fish and aquatic plants are estimated by multiplying the sediment RME and CTE COPEC levels by published COPEC-specific sediment-to-fish accumulation factors or by using published regression equations. Contaminant levels in benthic invertebrates reflect measured tissue samples collected from the Animas River.

Risk is quantified using the Hazard Quotient (HQ) method, which compares measured exposures (i.e., RME and CTE surface water, sediment and pore water EPCs) or estimated exposures (RME and CTE wildlife EDDs) to chronic surface water benchmarks, no-effect and effect sediment benchmarks, and wildlife TRVs.

A COPEC-specific HQ is calculated using the following general equation:

$$HQ = EPC \text{ or } EDD/\text{benchmark or } TRV$$

Where:

HQ	=	Hazard Quotient (unitless)
EPC	=	RME and CTE EPC (µg/L or mg/Kg)
EDD	=	RME and CTE EDD (mg/kg bw-day)
Benchmark	=	chronic surface water benchmark or sediment no effect and effect benchmark (µg/L or mg/kg, respectively)
TRV	=	no effect and effect wildlife TRV (mg/kg bw-day)

HQs equal to or above 1.0 identify a potential for ecological risk, whereas HQs below 1.0 are used to eliminate chemicals with assurance that they did not pose a risk.

Besides assessing the potential impacts associated with RME and CTE exposures, the risk characterization for fish and benthic invertebrates also views each surface water and sediment sample as an individual exposure event in time. Hence, HQs were calculated for all available surface water and sediment samples and were used to prepare “scatter plots” by sampling station and hydrologic period (i.e., pre-runoff, runoff, and post-runoff for surface water samples only). Those plots were then used to identify patterns of risk across the waterways and hydrologic periods. Minisipper surface water analytical data collected on a daily basis between mid-April

2014 and mid-July 2014 at four locations on the Animas River were used semi-quantitatively in the risk characterization to support the risk conclusions pertaining to fish.

Finally, toxicity data from fish and benthic invertebrates exposed to surface water and sediment in the laboratory were evaluated statistically to determine which of the observed responses were significantly different from the laboratory control sample (note: an upstream reference sample was not available for the statistical comparison due to a lack of reference locations that had not been impacted).

Uncertainty is inherent in this BERA because many assumptions were made in order to proceed with the investigation. These assumptions affect all aspects of the assessment including the CSM, the effects analysis, the exposure analysis, and the risk characterization. The uncertainty analysis identifies and discusses the major assumptions made in this BERA. The end result is a balanced overview of the degree of uncertainty in this report's results to help risk managers understand the full extent of potential ecological risk to aquatic community and wildlife receptors living or feeding in mainstem Cement Creek, mainstem Mineral Creek, and the Animas River at and below Silverton.

ES.2 Risk conclusions for benthic invertebrates

Taken together, the four independent measurement endpoints evaluated in this BERA (i.e., sediment HQs, pore water HQs, sediment toxicity, and community structure and function) indicate that the benthic invertebrate community is impacted in sections of the Animas River between A60 and BBridge, and in mainstem Cement and Mineral Creeks. The two creeks are the most impaired. In addition, comparing Multi-Metric Index (MMI) scores obtained from the Animas River starting in the early 1990's indicates that the benthic invertebrate community at sampling location A68 (located in the Animas River above mainstem Cement Creek) and at sampling locations A72 and A73 (located in the Animas River below mainstem Mineral Creek) have largely remained impaired over time. The MMI scores at locations further downstream on the Animas River (i.e., A75D and James Ranch [located below BBridge]) show a largely unimpaired benthic invertebrate community and Bakers Bridge appears to be moderately impaired.

ES.3 Risk conclusions for fish

- **Mainstem Cement Creek:**

The chemical conditions in surface water from mainstem Cement Creek are highly toxic to fish, particularly due to low pH and high Al, and to a lesser extent by the presence of Cd, Cu, and Zn. The toxicity tests show that surface water collected from this EU in November 2012 (i.e., post-runoff period) is acutely toxic to juvenile rainbow trout. The preponderance of evidence suggests that the fish community in mainstem Cement Creek (if present) would experience lethal stress under current conditions.

- **Mainstem Mineral Creek:**

The chemical conditions in surface water from mainstem Mineral Creek appear less severe than in mainstem Cement Creek for the local fish community. However, serious pH drops during the pre-runoff period coupled with high Al levels during the pre-runoff and post-runoff periods suggests that fish may experience high stress in the winter as well as summer and fall, but that survivors could possibly recover during the rest of the year (spring). The toxicity tests show that surface water collected from this EU in November 2012 (i.e., post-runoff period) and April 2013 (pre-runoff period) is acutely toxic to juvenile rainbow trout. The preponderance of evidence suggests that the fish community in mainstem Mineral Creek (if present) would likely experience high stress under current conditions.

- **Animas River above mainstem Cement Creek:**

The chemical conditions in surface water from this reach of the Animas River between A60 and A68 indicates the presence of one or more sources of metal contamination located further upstream in the watershed. The chemical signature of the surface water suggests that chronic toxicity to the fish community is possible, particularly due to the presence of Al, Cd, and Zn. Low pH, on the other hand, is not an issue in this reach. The presence of significant acute toxicity measured in juvenile rainbow trout acutely exposed to surface water from this reach further confirms the results of the chemical analyses. The preponderance of evidence suggests that the fish community in this reach of the Animas River is likely to be stressed during much of the year. This conclusion is supported by the fact that daily surface water samples collected between April and July 2014 using "MiniSipper" sampling devices positioned at location A56 (upstream of A60) showed the presence of potentially severe chronic toxicity associated with dissolved Al, Cd, Cu, Pb, and Zn during the pre-runoff and runoff periods.

- **Animas River between mainstem Cement Creek and mainstem Mineral Creek**

Little chemical information on the quality of the surface water is available because only two samples were collected and no acute toxicity testing was performed. The limited data suggest that this reach of the Animas River is likely to be lethal to fish, mostly due to low pH and high levels of aluminum, with secondary stress caused by Cd and Zn.

- **Animas River below mainstem Mineral Creek**

The chemical signature of the surface water in this reach of the Animas River reflects the major inputs from mainstem Mineral and Cement Creek, and the reach of the Animas River above mainstem Cement Creek. Surface water samples collected from sampling location A72 during the pre and post-runoff periods are acutely toxic to juvenile rainbow trout. Surface water samples collected during the same two hydrologic periods from the EUs further downstream do not show acute toxicity, suggesting that the effect has been "diluted out". However, the preponderance of evidence shows that Al, Cd, and Zn in surface water are likely to exert chronic effects on the fish

community to at least the BBridge EU located about 30 miles downstream from Silverton. This conclusion is supported by two additional lines of evidence:

- Daily surface water samples collected between April and July 2014 using "MiniSipper" sampling devices positioned at locations A73, A75D and BBridge showed the presence of low-grade and multi-week chronic toxicity associated with dissolved Al, Cd, and Zn during the pre-runoff and runoff periods.

- A fisheries survey performed by the Colorado Division of Wildlife (CDOW) in 2010 on the Animas River in the vicinity of sampling locations A72, A73, and A75D/A75B show a severe decline of the trout population at all three locations between 2005 and 2010. CDOW ascribed this collapse to a drastic reduction in surface water quality apparently associated with the discontinuance of a water treatment project in the Gladstone area on Cement Creek upgradient from Silverton. A 2014 follow-up fisheries survey by CDOW in the vicinity of sampling location A75D/A75B showed a continued decline in the local brook trout population.

ES.4 Risk conclusions for wildlife receptors

- **Animas River above mainstem Cement Creek**

Potential for minimal risk to wildlife receptors was identified for Zn (for the American dipper) and Pb (for the belted kingfisher). The American dipper was also used as a surrogate species to perform a conservative assessment of risk for the southwestern willow flycatcher—a federally and state-listed bird species. The evidence does not suggest that this species is at substantial risk from foraging in the Animas River above mainstem Cement Creek between sampling location A60 and A68.

- **Animas River below mainstem Mineral Creek**

The potential for risk to wildlife receptors in this reach of the Animas River is restricted to Cu in the American dipper at sampling locations A73B and A75B, with minor risk from Cu to the mallard (100% diet only) at the same two locations. The remaining COPECs are of no concern to any of the wildlife receptors because the HQs are below 1.0 for those metals. Benthic invertebrates were not collected for tissue residue analysis from sampling locations A73B and A75B. Hence, the levels of metals in benthic tissues at these two locations were estimated using conservative published sediment-to-benthic invertebrate regression models and uptake factors for use in the food chain model. It is noteworthy that the only two sampling locations with excessive risk from Cu are A73B and A75B. Given this pattern, the conclusion is that the risk from Cu is hypothetical and unlikely to be realized in the field.

The increased risk of Cu in the American dipper versus the mallard is driven almost entirely by the higher food ingestion rate of the former compared to the latter (0.0519 kg/kg/BW-day, Dry

Weight (dw), versus 0.2173 kg/kg BW-day, dw which results in a ratio of 4.2). This difference is driven by the fact that the average adult American dipper weighs 0.0565 kg and the average adult mallard weighs 1.162 kg. As such, the American dipper is a suitably sensitive wildlife receptor for future risk evaluations on this river system.

1.0 GENERAL INTRODUCTION

1.1 Scope

This report is a Baseline Ecological Risk Assessment (BERA) for the aquatic habitats in the Upper Animas River Mining District, located in San Juan County, CO. This report is a follow-up to a Screening-Level Ecological Risk Assessment (SLERA) finalized in 2013 (TechLaw, 2013).

The SLERA identified numerous Contaminants of Potential Ecological Concern (COPECs) for community-level and wildlife receptors associated with mainstem Cement Creek, mainstem Mineral Creek and the Animas River upstream and downstream of Silverton. Those COPECs were further analyzed to determine if they represented a risk to various receptor groups in the three waterways. As such, the SLERA provided an initial and conservative assessment of risk, and allowed for the determination to be made if enough information was available to support decision making. The SLERA identified unacceptable risk to both community-level and wildlife receptors, which prompted the need for additional sampling to provide more data for use in this BERA.

These data were collected in 2012 and 2013 for inclusion in an initial draft BERA report submitted to the Environmental Protection Agency (EPA) in February 2014. This expanded evaluation did not attempt to separate natural background contamination from past mining-related contamination, but instead assessed the risk from all sources combined. The draft BERA was reviewed by EPA and helped identify remaining data gaps that were addressed during additional sampling in April, May and September 2014 (TechLaw, 2014). This BERA is the result of these efforts.

The Animas River is divided into three reaches to support this BERA, as follows:

- *The Animas River above mainstem Cement Creek*: this reach of the Animas River covers about two river-miles between sampling locations A60 and A68. Location A56, which is situated about 1,000 ft upgradient of A60, represents regional "upstream" conditions. A56 is located just above the Mayflower Mill and Arrastra Creek. Location A68 is about 1,000 ft upstream of the confluence with Cement Creek and is therefore not influenced by the creek (see **Figure 1.1**). Note that the naming of this stretch of the Animas River is arbitrary, and that no samples collected upgradient from sampling location A56 are included in this BERA. Also, the text of this BERA does not refer to sampling location A56 as "reference" or "background" because sources of contamination are known to exist in the watershed upstream from A56.

- *The Animas River between mainstem Cement Creek and mainstem Mineral Creek*: this reach of the Animas River covers about one river-mile between the confluences of the two creeks. Location A69A is about 3,000 ft downstream of the confluence with

mainstem Cement Creek (just upstream of Idaho Gulch), whereas location A70B is just upstream of the confluence with mainstem Mineral Creek (see **Figure 1.1**).

- *The Animas River below mainstem Mineral Creek*: this reach of the Animas River covers about 30 river-miles between sampling locations A71B and Bakers Bridge (BBridge) (see **Figures 1.1 and 1.2**). The following values represent the approximate distance (in river-miles, where appropriate) separating the point where mainstem Mineral Creek enters the Animas River in Silverton and the downstream sampling locations: A71B (300 ft), A72 (3,500 ft), A73/A73B (5.9 miles), A75D/A75B (18.9 miles), and BBridge (30 miles). Note that the naming of this stretch of the river is also arbitrary, and that no samples collected downgradient from BBridge are assessed in this BERA.

Two additional waterways are also included in this BERA, as follows:

- *Mainstem Cement Creek*: the section evaluated in this BERA is represented by sampling locations CC48 and CC49, found on the creek just upstream of the confluence with the Animas River (see **Figure 1.1**). The SLERA (TechLaw, 2013) also evaluated two more locations upstream from CC48, but these are not included in this BERA because the SLERA showed that neither one could support aquatic life under current conditions.

- *Mainstem Mineral Creek*: the section evaluated in this BERA is represented by sampling location M34, found on the creek just upstream of the confluence with the Animas River (see **Figure 1.1**).

Each of these five stream and river reaches are evaluated as separate Exposure Units (EUs) to select COPECs, calculate exposures, and quantify the potential for ecological risk.

1.2 General ecological risk assessment approach

The following guidance and reference documents were used to prepare this BERA:

- EPA, 1997. *Ecological Risk Assessment for Superfund: Process for Designing and Conducting Ecological Risk Assessments, Interim Final*. Environmental Response Team, Edison, NJ.

- EPA, 1998. *Guidelines for Ecological Risk Assessment*. EPA/630/R-95/002F. EPA (1997) provides the general framework for planning and conducting the investigation.

1.3 Goals and objectives

Benthic invertebrates and fish represent the valued ecological resources to be protected in mainstem Cement Creek, mainstem Mineral Creek, and the Animas River above, across from,

and below Silverton (the "Site"). In addition, four representative species of aquatic-dependent birds and mammals were also retained as ecological resources to be protected in the Animas River. These community-level and wildlife receptors provide the basis to develop Site goals and objectives, and to select assessment endpoints for this BERA.

The ecological risk management goal for the Site is defined as follows:

> *"Promote healthy communities of aquatic and wildlife receptors in the waterways affected by Site-related contamination."*

Four ecological risk assessment objectives were identified to accomplish this goal:

- Identify the presence of Site-related COPECs that may pose a threat to one or more of the receptor groups;

- Document the potential exposure to those receptor groups using the available analytical datasets;

- Develop risk estimates and discuss major uncertainties; and

- Provide data for risk managers to determine the potential for ecological risk and to have enough information to support the risk management decision-making process.

This report recognizes that mainstem Mineral Creek upstream of the confluence with South Fork Mineral Creek, and mainstem Cement Creek, may not have supported a viable fish or invertebrate community before large-scale mining activities started in the 19^{th} century due to naturally-high levels of metals and low pH levels in those surface waters (Church *et al.*, 2007). These two waterways are nonetheless included in this report in order to provide a conservative risk evaluation and help identify risk drivers and exposure pathways of concern. It is expected that evaluating these naturally impaired waterways within a risk-based context will provide more information to support a scientific management decision point for discussion among the various stakeholders.

2.0 BASELINE PROBLEM FORMULATION

2.1 Data processing

2.1.1 Compiling a database for use in this BERA

The final product of the data evaluation and summarization process is a comprehensive database for all the surface water, sediment, pore water and benthic tissue analytical data collected between May 2009 and September 2014 for the Site.

Individual data sets were developed by compiling analytical results for each matrix of interest (i.e., surface water, sediment, pore water, benthic tissues), analyte group (i.e., total metals, dissolved metals, and pH), EU (i.e., mainstem Cement Creek, mainstem Mineral Creek, and the three Animas River reaches), and sampling locations within each EU, if applicable.

- **Appendix 1** provides the analytical data for pH, hardness, and total and dissolved metals concentrations measured in surface water from mainstem Cement Creek, mainstem Mineral Creek, and the three reaches of the Animas River between May 2009 and September 2014.
- **Appendix 2** provides the analytical data for total metals in bulk sediment samples collected from mainstem Cement Creek, mainstem Mineral Creek, and the three reaches of the Animas River in between 2012 and September 2014.
- **Appendix 3** provides the analytical data for hardness and dissolved metals measured in the pore water samples collected from the Animas River.
- **Appendix 4** provides the tissue residue data (both wet weight and dry weight) for the benthic invertebrates collected from the Animas River in September 2014.

Tables 2.1, 2.2 and 2.3 summarize the surface water, sediment, and pore water sampling efforts, respectively, that have occurred in the various EUs between May 2009 and September 2014. (Note: Section 4.3 explains how surface water samples collected in different months between May 2009 and September 2014 are combined into three distinct hydrologic periods for use in the exposure calculations). The surface water sampling efforts in support of this BERA focused heavily on sampling locations A68 (Animas River above mainstem Cement Creek), A72 (Animas River below mainstem Mineral Creek), CC48 (mainstem Cement Creek close to the confluence with the Animas River) and M34 (mainstem Mineral Creek close to the confluence with the Animas River). The other sampling locations were either not sampled or sampled only occasionally.

2.1.2 Data summarization method

The analytical data for total metals (unfiltered samples), dissolved metals (filtered samples), and pH in mainstem Cement Creek, mainstem Mineral Creek, the three Animas River reaches are summarized separately by waterway, as follows:

- frequency of detection (number of detected values over the number of samples analyzed),
- minimum detected value (with data qualifier),
- maximum detected value (with data qualifier), and
- sampling location of the maximum detected value.

The following procedures were applied to compile data for a metal in a given matrix to calculate the summary statistics used in this BERA:

- Results assigned qualifiers indicating that an analyte was positively detected or presumptively present (i.e., data without flags or flagged as "D" [diluted] or "J" [estimated]) were retained as reported for use in the exposure calculations.

- Results assigned qualifiers indicating that an analyte was not positively detected (i.e., data flagged as "U" [non-detected] or "UJ" [estimated non-detected]) were retained at one-half their Detection Limit (DL).

- Any results considered of inadequate quality (i.e., data qualified as "R") were not used in the risk calculations.

- Analytical results for samples collected from the same location but during different sampling events were considered unique samples and were not combined.

- Analytical data from duplicate samples (i.e., samples collected at the same location and date) were averaged. These data were handled as follows:

    - If both samples had a detected value, the average concentration and the most conservative of the two data qualifiers was used as the maximum value (e.g., if one value had no flag and the second value was flagged as "J", then the average concentration was calculated and flagged as "J").

    - If one of the duplicates had a detected value and the other had an undetected value, then only the detected value and its associated flag (if applicable) was used as the maximum value. This approach was necessary because in some cases the undetected value was substantially higher than the detected value due to a difference in the way the samples were diluted, thus affecting the DLs. Taking an average of these two numbers would have artificially inflated the maximum value.

- If the values in both samples were non-detect, then the highest of the two method DLs was used.

2.2 Problem formulation

2.2.1 Environmental setting and contaminants at the Site

2.2.1.1 Brief Site description and history

The information summarized in this subsection was obtained from Church, S.E., P. von Guerard, and S.E. Finger, eds., 2007. *Integrated investigations of environmental effects of historical mining in the Animas River watershed, San Juan County, Colorado. U.S. Geological Survey Professional Paper 1651*, 1,096p. plus CD-ROM (in two volumes), and EPA, 2012. *Final Sampling and Analysis Plan/Quality Assurance Project Plan. 2012 Sampling Events. Upper Animas Mining District, Gladstone, San Juan County, Colorado (May 2012).*

The mining district is located in the northernmost headwaters of the Animas River watershed in San Juan County, CO. It covers the drainage basin of the Animas River at and upstream of the town of Silverton, CO, its two main tributaries (i.e., Cement Creek and Mineral Creek), and the Animas River below the confluence with Mineral Creek. Elevations in the watershed range between about 9,000 ft and 13,500 ft.

The discovery of gold and silver brought miners to the area in the early 1870’s. The discovery of silver in the base-metal ores was the major factor in establishing Silverton as a permanent settlement. Between 1870 and 1890, the richer ore deposits were discovered and mined. Not until 1890 was a serious attempt made to mine and concentrate the larger low-grade ore bodies in the area. Twelve concentration mills operated in the valley by 1900. All sent their products to the Kendrick and Gelder Smelter near the mouth of Cement Creek in Silverton.

Mining and milling operations slowed down around 1905, and mines were consolidated into fewer and larger operations with the facilities for milling large volumes of ore. After 1907, mining and milling continued in the basin whenever prices were favorable. Gladstone, located about eight miles upstream of Silverton on Cement Creek, is the site of an historic mining town developed in the 1880s in response to the onset of mining. The town was the central location and railroad terminus for milling and shipping mine ores from the surrounding valley. Gladstone declined in the 1920’s and no remnants of it remain visible today.

The Sunnyside Mine was the only active year-round mine left in the county by the 1970’s. This mine ceased production in 1991, and underwent extensive reclamation. The Gold King Mine’s permit with the Division of Reclamation, Mining and Safety was revoked by the Colorado Mined Land Reclamation Board and the financial warranty bond was forfeited in 2005.

The Sunnyside Mine was accessed through the American Tunnel which has its portal in Gladstone. The American Tunnel drained up to 1,600 gallons per minute (gpm) of water prior to bulkhead installations. The Standard Metals Corporation constructed a lime feed and settling pond-type treatment facility in Gladstone in 1979. Water discharging from the American Tunnel was treated as required by the water discharge permit. The facility operations and mine ownership was later transferred to the Sunnyside Gold Corporation (SGC). SGC installed eleven bulkheads within the Sunnyside Mine as part of a court-ordered consent decree to terminate their discharge permit. These bulkheads greatly reduced the volume of discharge from the American Tunnel. Currently, between 70 and 100 gpm continue to discharge from the American Tunnel, presumably from near-surface groundwater.

The treatment facility, operations, and permit were transferred to the Gold King Mines Corporation in January 2003. The settling ponds were deeded to the San Juan Corporation by SGC prior to the lease between the Gold King Mines and San Juan Corporations. The treatment facility continued to treat the American Tunnel discharge and the Gold King discharge until September 2004. The San Juan Corporation required SGC to reclaim the four settling ponds (completed in 2005) when the San Juan Corporation and the SGC lease were terminated. The Gold King Mines Corporation was subsequently evicted and the balance of the Gold King Mines Corporation land was acquired by the San Juan Corporation as the lien-holder. The American Tunnel portal reclamation and the removal of some out-buildings were completed in 2006. The Bureau of Land Management (BLM) manages land associated with the American Tunnel portal and its immediate vicinity, whereas the San Juan Corporation owns most of the surrounding land.

Many abandoned mines exist within a two-mile radius of Gladstone. They include: the Upper Gold King 7 Level, American Tunnel, Grand Mogul, Mogul, Red and Bonita, Eveline, Henrietta, Joe and John, and Lark mines. Some of these mines have acid mine drainages that produce flows of between 30 and 300 gpm that directly or indirectly enter Cement Creek and eventually reach the Animas River. The Animas River Stakeholder Group, the BLM, and the Division of Reclamation, Mining and Safety have completed remediation projects at the Eveline, Henrietta, Joe and John, and Lark mines.

Existing and historical data suggest that conditions have changed recently at several locations where site-impacted waters enter upper Cement Creek. For example, flows have increased at the Red and Bonita mine and the upper Gold King 7 Level. The data also show higher levels of Al, Cd, Cu, Mn and Zn in Cement Creek, and downstream in the Animas River at and below Silverton between 2005 and 2007. These increases coincide with the end of active water treatment in Gladstone in 2005 and the installation of bulkheads at the American Tunnel.

The headwaters and tributaries of Cement Creek, Mineral Creek, and the Animas River originate in treeless alpine regions. With a few exceptions, the streams follow high-gradient, narrow glaciated valleys. The vegetation along those valleys is rather sparse in the presence of extensive areas of exposed rock and talus (i.e., a sloping mass of rock debris at the base of a cliff).

Past surveys of fish and benthic invertebrate communities showed that the headwaters of the Animas River above Silverton, the main stems of Cement and Mineral Creeks, and several smaller tributaries support little or no aquatic life due to the presence of site-related contamination. On the other hand, South Fork Mineral Creek and several tributaries of the upper Animas River drain basins that provide substantial acid-neutralizing capacity and support viable trout populations. The Animas River between Maggie Gulch (located about eight river-miles upstream from Silverton) and the mouth of Cement Creek in Silverton, supports brook trout and a moderately impaired invertebrate community (see Chapters D and E18 in Church *et al.*, 2007), which suggests substantial improvements in surface water quality since the 1970's. Note, however, that sections of the Animas River further upstream from Maggie Gulch are still severely impacted by past mining activities. The stream biota in the Animas River downstream from Silverton are also degraded due to input from Cement and Mineral Creeks (see Chapters A, D, E18, and E19 in Church *et al.*, 2007).

2.2.1.2 Past sampling of environmental media

This evaluation uses analytical data from surface water and sediment collected between 2009 and 2014 from the Animas River, mainstem Cement Creek, and mainstem Mineral Creek. The BERA also evaluates two rounds of pore water samples collected from the Animas River above mainstem Cement Creek and below mainstem Mineral Creek in April and September 2014. This approach ensures that the aquatic exposures reflected "current" conditions.

2.2.1.3 Suspected contaminants

Acid conditions result from the interaction of sulfide minerals, water, and oxygen, which together yield highly-acidified drainage water. This water dissolves metals present in bedrock, veins, ore, tailings, and waste rock, such as Al, Cd, Cu, and Zn. These dissolved metals are then transported over land or via groundwater to small tributaries that connect to the Site.

The higher pH of the surface water in the Animas River above the confluence with mainstem Cement Creek could cause some of the dissolved metals brought in by the two creeks to precipitate out of solution and become integrated into the substrate. Metals may also be carried in particulate form (e.g., fine tailings) by the water current and deposited in lower-energy areas of the affected waterways. Previous investigations showed that numerous metals in surface water samples from the three targeted waterways exceeded applicable water quality standards (see Chapter D in Church *et al.*, 2007).

2.2.2 Ecological resources potentially at risk

The ecological resources of concern in this BERA consist of (a) fish exposed to metals in surface water, (b) benthic invertebrates exposed to metals in sediment and pore water, and (c) representative species of wildlife receptors exposed to metals in surface water, sediment, and

prey items obtained from the Animas River above mainstem Cement Creek and below mainstem Mineral Creek.

A list of Threatened and Endangered (T&E) species was obtained from the Colorado Wildlife Heritage Foundation and from the Colorado Parks and Wildlife species of concern list for San Juan County, CO (updated December 2011). Two mammals identified on the lists are the lynx (*Lynx Canadensis)* and the wolverine (*Gulo gulo)*. The lynx is listed as federally threatened and state endangered, while the wolverine is listed as state endangered. The boreal toad (*Bufo boreas boreas)* is listed as state endangered. For birds, the southwestern willow flycatcher (*Empidonax trailii extimus)* is listed as federally endangered and state endangered. This protected species, if present in the riparian habitat along the Animas River at and below Silverton, is assumed to have the potential for exposure to Site-derived contamination.

The southwestern willow flycatcher is a small passerine bird which breeds in dense riparian habitats along rivers, streams, or wetlands and feeds on insects. The riparian vegetation can be dominated by dense growths of willows (*Salix* sp.), seepwillow (*Baccharis* sp.), or other shrubs and medium-sized trees. An overstory of cottonwood (*Populus* sp.), tamarisk (*Tamarix* sp.), or other large trees may be present but this is not necessary. In some areas, the flycatcher nests in habitats dominated by tamarisk and Russian olive (*Eleagnus angustifolia*). A key characteristic of breeding habitat appears to be the presence of dense vegetation, usually throughout all vegetation layers present within the habitat.

Almost all southwestern willow flycatcher breeding habitats are less than 20 yards from water. At some sites, surface water is present early in the nesting season, but gradually dries up as the season progresses. Ultimately, the breeding site must have a water table high enough to support riparian vegetation.

Suitable riparian habitat for the southwestern willow flycatcher is available along the shoreline of the Animas River downstream of Silverton, and especially at the lower elevations below BBridge and James Ranch. This BERA conservatively assumes that the species might be present based on its listing in San Juan County and the existence of riparian habitat. The American dipper (see further below) served as a surrogate for the southwestern willow flycatcher.

2.3 Preliminary fate and effects evaluation

A preliminary evaluation of the fate and transport of Site-related contamination helps identify potentially complete exposure pathways. A brief summary of the fate and effects information, together with data on the ecotoxicity of Site-related contamination to the community-level and wildlife receptors are discussed below.

2.3.1 Fate and transport

The information provided by Church *et al*. (2007) was reviewed to determine which fate and transport mechanisms might result in complete exposure pathways to aquatic, community-level receptors in the three targeted waterways or to wildlife receptors feeding on aquatic food items in the Animas River (Note: The BERA assumes that wildlife receptors forage only in the Animas River because fish and aquatic invertebrates appear to be largely absent from mainstem Cement and large portions of Mineral Creeks under current conditions).

The goal was to identify the major elements of a complete exposure pathway, which consist of the following components:

- source(s) of contamination,
- release and transport mechanisms,
- contact points and exposure media,
- routes of entry, and
- key receptors.

Each of these components is discussed below.

- **Sources of contamination**

The major sources of contamination relating to past mining in the watersheds of Cement Creek, Mineral Creek, and the Animas River above Silverton consist of one or more of the following activities: tunneling to reach the ore veins and to drain groundwater out of mine workings, disposal of waste and overburden rock, and disposal of mine tailings on land and in waterways.

Additionally, natural sources of regional contamination consist of groundwater that has come in to contact with undisturbed mineralized materials.

- **Release and transport mechanisms**

Some of the rocks are enriched with sulfide minerals (e.g., pyrrhotite, pyrite and chalcopyrite). These minerals react with water and atmospheric oxygen over time. The oxidation process generates sulfuric acid, which in turn causes metals to dissolve out of host rock, vein rock, waste rock, and tailings. This highly-acidic and metal-rich effluent is toxic to aquatic receptors due to its low pH and high dissolved metals content.

The following release and transport mechanisms may potentially affect the concentration and spatial distribution of metals in the affected waterways:

- dissolution and leaching of metals from mine waste, host rock, or vein rock into groundwater,
- migration of metals in groundwater to sediment and surface water in adjacent surface water bodies, and its attenuation by dilution or dispersion and sorption,
- transport of metals adsorbed to soil and tailings particles via terrestrial runoff,
- transport of metals in surface water runoff, and
- trophic transfer of metals incorporated in aquatic food chains.

The potential release of Site-related contamination and its transport from the sources to points of contact with aquatic receptors in the three targeted waterways depends on its chemical speciation, concentration, presence of nearby surface water bodies, and the extent and duration of precipitation or snowmelt events. Surface water runoff and groundwater infiltration are particularly important transport mechanisms for soluble species of metals.

- **Contact point and exposure media**

Mainstem Cement Creek, mainstem Mineral Creek, and the three reaches of Animas River above, across, and below Silverton are the contact points evaluated in this BERA. The exposure media are as follows:

- surface water,
- sediment,
- pore water, and
- prey items for wildlife receptors (only in the Animas River above and below Silverton).

- **Routes of entry**

The main routes of entry evaluated in this BERA for aquatic community-level receptors, and wildlife receptors feeding on aquatic prey, are as follows:

- direct contact with surface water, sediment or pore water via dermal or gill absorption (aquatic community-level receptors),
- surface water ingestion (wildlife receptors),
- incidental sediment ingestion (wildlife receptors), and
- ingestion of contaminated food items (wildlife receptors).

Exposure to metals via inhalation or skin absorption is omitted because it is considered to be minor for wildlife receptors feeding on aquatic food items.

- **Key receptors**

    - **Aquatic receptors**

This BERA assumes that benthic invertebrates live on and within the substrate in mainstem Cement Creek, mainstem Mineral Creek, and the three reaches of the Animas River. It also assumes that fish live in the water column of mainstem Cement Creek, mainstem Mineral Creek, and the three reaches of the Animas River.

- **Wildlife receptors feeding on aquatic food items**

This BERA assumes that the following types of wildlife receptors could become exposed to Site-related contamination while feeding in the three reaches of the Animas River: (a) invertivorous birds, (b) omnivorous birds, (c) piscivorous birds, and (d) herbivorous mammals. Wildlife receptors were not evaluated for risk in mainstem Cement Creek and mainstem Mineral Creek because these two waterways are too impacted under current conditions to provide forage to consistently sustain wildlife populations. Wildlife receptors are also not evaluated for risk from the Animas River between mainstem Cement Creek and mainstem Mineral Creek in Silverton because this reach was not sampled for sediment, which was needed to estimate the contaminant levels in the food items ingested by the wildlife receptors.

- **Ecotoxicity**

Acidity and metals are the two major chemical stressors in the aquatic habitats of interest to this BERA.

Acidity/low pH

Sulfuric acid is released when water and oxygen interact with sulfide-rich materials. Low pH is toxic to aquatic receptors. Sensitive species of fish and aquatic invertebrates experience increased mortality at a pH of around 6.0. For example, brook trout populations are known to disappear from streams when pH drops to the lower 5.0 range for an extended period of time. Other trout species (e.g., rainbow trout or brown trout) are considered more sensitive to increased acidity and are therefore affected sooner than brook trout.

Metals

High acidity solubilizes metals, resulting in metals-enriched surface water runoff. Dissolved metals are of the highest concern because, unlike metals associated with the particulate fraction, they are bioavailable to exert direct toxicity to aquatic receptors.

The relative sensitivity of four trout species (namely, brook trout, brown trout, rainbow trout and cutthroat trout) to Cd, Cu, and Zn was determined in support of this BERA (see **Appendix 5**). The four trout species included in this evaluation may be found in the Animas River above and below Silverton. The three metals of concern are known to be associated with past and current mining and non-mining-related releases in the Animas River watershed. Al is also a key

contaminant present in the Animas River. However, this metal is not included in **Appendix 5** because not enough trout-specific toxicity data were found to derive acute and chronic toxicity threshold values.

A literature search was performed to obtain 96-hour acute toxicity data on juvenile life stages to derive acute toxicity thresholds for the three target metals. These thresholds were standardized to a hardness of 50 mg/L $CaCO_3$ to allow for a direct comparison of species sensitivity to the three metals.

The table below summarizes the results of this effort. **Appendix 5** provides additional details on the literature search criteria and statistical analysis of the data.

Relative sensitivity of four trout species to three metals in surface water			
Trout Species	**Target metal**	**Acute toxicity thresholds**	**Relative sensitivity**
Brook trout	cadmium	1.15 µg/L	1
brown trout	cadmium	1.21 µg/L	2
rainbow trout	cadmium	1.33 µg/L	3
rainbow trout	copper	13.4 µg/L	1
brown trout	copper	18.1 µg/L	2
brook trout	copper	22.7 µg/L	3
cutthroat trout	copper	24.4 µg/L	4
rainbow trout	zinc	121 µg/L	1
cutthroat trout	zinc	141 µg/L	2
brown trout	zinc	283 µg/L	3
brook trout	zinc	732 µg/L	4

The information provided in the table above can be summarized as follows:

Cadmium

- Acute toxicity data for brook trout, brown trout, and rainbow trout were available to calculate Cd acute toxicity thresholds. It is not known how much more or less sensitive cutthroat trout may be compared to these three species.
- The difference in acute toxicity thresholds between the three trout species was minimal and unlikely to be significant.
- Cd was the most acutely toxic of the three target metals to trout.

Copper

- Acute toxicity data were available to calculate Cu acute toxicity thresholds for all four trout species.
- The rainbow trout was over two times more sensitive to Cu than the cutthroat trout. The sensitivities of brown trout and brook trout fell between these extremes.
- The acute toxicity of Cu fell in between that of Cd and Zn.

Zinc

- Acute toxicity data were available to calculate Zn acute toxicity thresholds for all four trout species.
- The rainbow trout was six times more sensitive to Zn than the brook trout. The sensitivities of cutthroat trout and brown trout fell between these extremes.
- Zn was the least acutely toxic of the three target metals.

Based on this information, it can be concluded that the rainbow trout appears to be consistently very sensitive to the three metals. The relative sensitivities of the other three species to Cu and Zn are not so consistent and vary by species.

Both acidity and dissolved metals affect osmoregulation in aquatic organisms by changing the integrity of the cell junctions in the gill tissues. The cell junctions become “leaky” with increasing levels of H^+ (protons) or metals, thereby allowing blood electrolytes to diffuse out of the gill tissue, and water to diffuse into the bloodstream. Death results when blood electrolyte levels drop below a critical physiological threshold, which varies from species to species.

2.3.2 Ecosystems potentially at risk

The potentially impacted aquatic habitats evaluated in this BERA consist of mainstem Cement Creek, mainstem Mineral Creek, and three reaches of the Animas River, as follows: Animas River above the confluence with mainstem Cement Creek (about 2 miles, between sampling locations A60 to A68), Animas River between mainstem Cement Creek and mainstem Mineral Creek (about 1 mile, represented by sampling locations A69A and A70B), and Animas River below mainstem Mineral Creek (about 30 miles, between sampling locations A71B and BBridge).

2.3.3 Complete exposure pathways

Routes of exposure are the means by which COPECs can be transferred from a contaminated medium to ecological receptors. This BERA evaluates the following receptors and exposure routes:

- *Benthic invertebrates*: direct contact with sediment and pore water collected from mainstem Cement Creek (sediment only), mainstem Mineral Creek (sediment only), and the Animas River above mainstem Cement Creek (sediment and pore water) and the Animas River below mainstem Mineral Creek (sediment and pore water). Exposure of benthic invertebrates to substrate from the Animas River between mainstem Cement Creek and mainstem Mineral Creek could not be evaluated because no sediment samples were collected from this reach.

- *Fish*: direct contact with surface water in all three waterways.

- *Invertivorous birds*: ingestion of surface water, sediment, and benthic invertebrates from the Animas River above mainstem Cement Creek and below mainstem Mineral Creek.

- *Omnivorous birds*: ingestion of surface water, sediment, benthic invertebrates, and aquatic plants from the Animas River above mainstem Cement Creek and below mainstem Mineral Creek.

- *Piscivorous birds*: ingestion of surface water, sediment, and fish from the Animas River above mainstem Cement Creek and below mainstem Mineral Creek (note: the belted kingfisher, which is the modeled piscivorous bird, is assumed to ingest a small amount of sediment because, even though this species primarily eats fish captured from within the water column, it is also known to feed on crayfish, stonerollers, and sculpin found right on the substrate).

- *Herbivorous mammals*: ingestion of surface water, sediment, and aquatic plants from the Animas River above mainstem Cement Creek and below mainstem Mineral Creek.

2.4 Target receptors

2.4.1 Introduction

Endpoints are selected to help quantify the risks to representative receptors that may be exposed to metals and low pH associated with current mine releases.

Assessment endpoints represent explicit expressions of the key ecological resources to be protected from harm. They should reflect sensitive populations, communities, or trophic guilds. Four criteria used for selecting the proposed assessment endpoints for the BERA are listed below. The ecological resource should:

- have relevance to the local ecosystem,
- be susceptible to the stressors of concern,
- have biological, social, or economic value, and
- be relevant to the risk management goals for the Site.

By considering these selection criteria, risks identified to one or more of the assessment endpoints will help inform risk management decisions at the Site.

Measures of effect represent measurable ecological characteristics, quantified through laboratory or field experimentation, which can be related back to the valued ecological resources chosen as the assessment endpoints. Measures of effect are required because it is often not possible to directly quantify risk to an assessment endpoint. The measures of effect represent the same exposure pathway(s) and mechanisms of toxicity as the assessment endpoints in order to be relevant and useful.

Risk questions establish a link between assessment endpoints and their predicted responses when exposed to COPECs. The risk questions should provide a basis to develop the study design and evaluate the results of the Site investigation in the analysis phase and during risk characterization (EPA, 1997).

2.4.2 Representative species or communities

It is neither practical nor possible to evaluate the potential for ecological risk to all of the individual parts of the local aquatic ecosystem potentially affected by Site-related contamination. Instead, key components are identified to select those species or groups most likely to experience exposure to the stressors.

2.4.2.1 Community-level receptors

<u>Benthic invertebrates</u>

Benthic invertebrates form an integral link in all aquatic ecosystems. They play a key role in nutrient and energy transfers within those systems. They also process and assimilate organic material, feed on other invertebrates, and are themselves consumed by fish, birds, and mammals.

Metals with the potential to bioaccumulate can be transferred from the surface water, sediment or pore water into the benthic invertebrate community and up the food chain, thereby harming higher-level receptors. Significant alterations in invertebrate communities could also impact the energy cycling at the base of the aquatic food chain.

The substrate in the three waterways of interest in this BERA should be able to support a diverse benthic invertebrate community. Key invertebrates include amphipods and the aquatic life stages of numerous insect species (e.g., mayflies, stoneflies, caddisflies, dragonflies, etc.).

Note that it is considered possible that mainstem Mineral Creek upstream of the confluence with South Fork Mineral Creek, and mainstem Cement Creek, may not have supported a macroinvertebrate community before large-scale mining activities started in the 19th century (Church *et al*., 2007) due to naturally high levels of metals and low-pH levels. However, this BERA conservatively evaluates the potential ecological risk to a hypothetical benthic invertebrate community in these waterways in order to assess the current conditions. The outcome of this evaluation should be interpreted in a broader context, which considers naturally-altered surface water and substrate conditions.

<u>Fish</u>

The Animas River should be able to support a healthy fish community, consisting of cold-water stream species, such as trout and sculpin. The aquatic environment should provide such a community with a diverse food base, suitable feeding and spawning areas, refuges for juvenile fish, and other essential environmental services.

The presence of metals in the surface water and sediment can impair the local fish community in two general ways: (1) mortality of sensitive early-life stages exposed to dissolved metals in the

water column or pore water, or (2) high metal concentrations in aquatic biota via food chain uptake, which could affect reproduction and the long-term survival of the exposed fish.

As with the benthic invertebrate community, it is considered possible that mainstem Mineral Creek upstream of the confluence with South Fork Mineral Creek, and mainstem Cement Creek, may not have supported fish before large-scale mining activities started in the 19th century (Church *et al*., 2007). However, this BERA conservatively evaluates the potential ecological risk to a hypothetical fish community in these waterways in order to assess the current conditions. The outcome of this evaluation should be interpreted in a broader context, which considers naturally altered surface water conditions.

2.4.2.2 Wildlife receptors

The Colorado Parks and Wildlife Natural Diversity Information Source was accessed online to obtain a list of known or likely species occurrence in San Juan County, CO (see **Appendix 6**). This county encompasses the Animas River upstream and downstream of Silverton.

The information below lists select bird and mammal species found in San Juan County that may obtain some or all of their food from an aquatic environment. Note, however, that it is unknown if any of these species actually inhabit the reaches of the Animas River specifically evaluated in this BERA.

Birds:

- great blue heron (*Ardea Herodias*): piscivore
- belted kingfisher (*Ceryle alcyon*): piscivore
- American dipper (*Cinclus mexicanus*): aquatic insectivore
- Canada goose (*Branta Canadensis*): herbivore
- mallard (*Anas platyrhynchos*): aquatic and terrestrial herbivore and invertivore
- common merganser (*Mergus merganser*): piscivore
- spotted sandpiper (*Actitis macularius*): benthivore
- northern rough-winged swallow (*Stelgidopteryx serripennis*): aquatic insectivore
- barn swallow (*Hirundo rustica*): aquatic insectivore

Mammals:

- American beaver (*Castor Canadensis*): herbivore
- big brown bat (*Eptesicus fuscus*): insectivore
- common muskrat (*Ondatra zibethicus*): herbivore
- mink (*Mustela vison*): carnivore, including fish and crayfish
- water shrew (*Sorex palustris*): aquatic insectivore

Four kinds of bird and mammal species are assessed in this BERA using food chain modeling to calculate metal-specific daily exposures from drinking surface water, ingesting sediment, and feeding on aquatic food items from the Animas River above and below Silverton. This BERA does not calculate exposures for wildlife receptors that might feed in mainstem Cement Creek and mainstem Mineral Creek because these two waterways do not support viable aquatic invertebrate and fish communities under current conditions and therefore cannot provide a food base. This BERA evaluates the following target wildlife receptors:

- Invertivorous birds: represented by the American dipper (*Cinclus mexicanus*)

The American dipper is a small passerine bird, which forages on the bottom of fast-moving rocky streams in mountainous regions of the western US. It dives to the bottom of the stream where it seeks out mainly aquatic insects and their larvae, but also small crustaceans (e.g., juvenile crayfish) or tiny fish and tadpoles. This species was selected for use in food chain modeling to represent birds, which feed on aquatic insects and benthic invertebrates. It also serves as a surrogate for the southwestern willow flycatcher, a listed species of passerine insectivore listed for San Juan County, CO, which may or may not be present in the riparian habitat of the Animas River above or below Silverton.

- Omnivorous birds: represented by the mallard (*Anas platyrhynchos*)

The mallard is a medium-sized dabbling duck with a flexible diet consisting of aquatic and terrestrial plants (including leaves, stems, seeds, roots and tubers), but also aquatic invertebrates (e.g., crustaceans and aquatic insects), and terrestrial invertebrates (e.g., worms, snails, slugs, beetles). This species was selected for use in food chain modeling to represent avian herbivores that also have the ability to switch to an invertivorous diet, particularly during the egg-laying season.

- Piscivorous birds: represented by the belted kingfisher (*Ceryle alcyon*)

The belted kingfisher is a piscivore which feeds mostly on fish that swim near the surface or in shallow areas of ponds, lakes, rivers, and streams. Depending on food availability and season, they may also feed on other aquatic species such as crayfish, mussels, insects, and amphibians, among others. The bird catches its prey by diving head-first into the water in flight or jumping from a perch along the shoreline. This species was selected for use in food chain modeling to represent piscivorous birds.

- Herbivorous mammals: represented by the muskrat (*Ondatra zibethicus*)

The muskrat is an aquatic rodent which feeds primarily on aquatic plants such as marsh grasses, sedges, cattails, bulrushes and green algae. The herbivorous diet can be complemented by small amounts of crayfish, mollusks, fish, frogs, turtles, and young birds. This species was selected for use in food chain modeling to represent semi-aquatic herbivorous mammals.

2.4.3 Selecting assessment endpoints and measures of effect

2.4.3.1 Assessment endpoints and risk questions

The BERA uses the following assessment endpoints to evaluate the potential risks to the aquatic receptors, and wildlife receptors feeding on aquatic food items from the Animas River above and below Silverton. A risk question is appended to each assessment endpoint.

The BERA assumes that by evaluating and protecting the assessment endpoints, all of the aquatic habitats, and the wildlife receptors feeding on them, are protected as well.

- **Maintain a stable and healthy benthic invertebrate community**: *are the metal levels in sediment and pore water from mainstem Cement Creek, mainstem Mineral Creek, and the Animas River above mainstem Cement Creek and below Mineral Creek high enough to impair the benthic invertebrates in these waterways?*

- **Maintain a stable and healthy fish community**: *are the metal levels in surface water from mainstem Cement Creek, mainstem Mineral Creek, and the Animas River above mainstem Cement Creek, between mainstem Cement Creek and mainstem Mineral Creek, and below Mineral Creek high enough to impair the fish in these waterways?*

- **Maintain stable and healthy invertivorous bird populations**: *are the metal levels in surface water, sediment, and benthic invertebrates high enough to impair invertivorous birds foraging in the Animas River above mainstem Cement Creek and below mainstem Mineral Creek?*

- **Maintain stable and healthy omnivorous bird populations**: *are the metal levels in surface water, sediment, benthic invertebrates, and aquatic plants high enough to impair omnivorous birds foraging in the Animas River above mainstem Cement Creek and below mainstem Mineral Creek?*

- **Maintain stable and healthy piscivorous bird populations**: *are the metal levels in surface water and fish high enough to impair piscivorous birds foraging in the Animas River above mainstem Cement Creek and below mainstem Mineral Creek?*

- **Maintain stable and healthy herbivorous mammal populations**: *are the metal levels in surface water, sediment, and aquatic plants high enough to impair herbivorous mammals foraging in the Animas River above mainstem Cement Creek and below mainstem Mineral Creek?*

2.4.3.2 Measures of effect

<u>Assessment endpoint #1</u>:

Maintain a stable and healthy benthic invertebrate community: *Are the metal levels in sediment and pore water from mainstem Cement Creek, mainstem Mineral Creek, and the Animas River above mainstem Cement Creek and below Mineral Creek high enough to impair the benthic invertebrates in these waterways?*

The BERA uses up to four measures of effect, depending on the EU, to assess the potential impacts of metals to this receptor group, as follows:

1.A Compare the metal levels measured in sediment samples to sediment benchmarks.

1.B Compare the metal levels measured in field-collected pore water samples to chronic surface water benchmarks.

1.C Assess survival and biomass in the amphipod *Hyalella azteca* exposed in the laboratory for ten days to sediment samples collected from mainstem Cement Creek, mainstem Mineral Creek, and the Animas River above mainstem Cement Creek and below mainstem Mineral Creek.

1.D Assess the benthic community structure and function based on field-collected invertebrate samples.

<u>Assessment endpoint #2</u>:

Maintain a stable and healthy fish community: *Are the metal levels in surface water from mainstem Cement Creek, mainstem Mineral Creek, and the Animas River above mainstem Cement Creek, between mainstem Cement Creek and mainstem Mineral Creek, and below mainstem Mineral Creek high enough to impair the fish in these waterways?*

This BERA uses two measures of effect to assess the potential impacts of metals to this receptor group, as follows:

2.A Compare metal levels measured in surface water samples to chronic surface water benchmarks.

2.B Assess survival in juvenile rainbow trout (*Oncorhynchus mykiss*) exposed for 96 hours in the laboratory to surface water samples collected from mainstem Cement Creek, mainstem Mineral Creek, and the Animas River above mainstem Cement Creek and below mainstem Mineral Creek.

<u>Assessment endpoint #3:</u>

Maintain stable and healthy invertivorous bird populations: *are the metal levels in surface*

water, sediment, and benthic invertebrates high enough to impair invertivorous birds foraging in the Animas River above mainstem Cement Creek and below mainstem Mineral Creek?

This BERA uses one measure of effect to assess the potential impacts of metals ingested by this receptor group, as follows:

3.A Use metal concentrations measured in sediment and benthic invertebrates in a food chain model to calculate metal-specific EDDs from ingesting surface water, sediment, and benthic invertebrates, and compare these EDDs to avian TRVs.

Assessment endpoint #4:

Maintain stable and healthy omnivorous bird populations: *are the metal levels in surface water, sediment, benthic invertebrates, and aquatic plants high enough to impair omnivorous birds foraging in the Animas River above mainstem Cement Creek and below mainstem Mineral Creek?*

This BERA uses one measure of effect to assess the potential impacts of metals ingested by this receptor group, as follows:

4.A Use metal concentrations measured in sediment samples to estimate metal residues in aquatic plants; use the estimated plant residues and the measured benthic invertebrate residues in a food chain model to calculate metal-specific EDDs from ingesting surface water, sediment, and food, and compare these EDDs to avian TRVs.

Assessment endpoint #5:

Maintain stable and healthy piscivorous bird populations: *are the metal levels in surface water and fish high enough to impair piscivorous birds foraging in the Animas River above mainstem Cement Creek and below mainstem Mineral Creek?*

This BERA uses one measurement endpoint to assess the potential impacts of metals ingested by this receptor group:

5.A Use metal concentrations measured in sediment samples to estimate metal residues in fish; use food chain modeling to calculate metal-specific EDDs from ingesting surface water and fish, and compare these EDDs to avian TRVs.

Assessment endpoint #6:

Maintain stable and healthy herbivorous mammal populations: *are the metal levels in surface water, sediment, and aquatic plants high enough to impair herbivorous mammals foraging in the Animas River above mainstem Cement Creek and below mainstem Mineral*

Creek?

This BERA uses one measurement endpoint to assess the potential impacts of metals ingested by this receptor group:

6.A Use metal concentrations measured in sediment samples to estimate metal residues in aquatic plants; use food chain modeling to calculate metal-specific EDDs from ingesting surface water, sediment, and aquatic plants, and compare these EDDs to mammalian TRVs.

2.5 Conceptual Site Model

The CSM provides the foundation of a problem formulation. The CSM was developed based on knowledge of natural and man-made sources, contaminants, complete exposure pathways, and likely ecological receptors. The model shows how metals move from the contaminant sources through the exposure media to the receptors. **Figure 2.1** presents the CSM for this BERA.

The primary source of contamination to the local waterways consists of water which has come into contact with local rock, either naturally or as a result of mining activities, such as through the creation of adits. Sulfuric acid is released when water and oxygen interact with the sulfide-rich mine wastes, host rock, or vein rock. This acid dissolves metals that enter the waterways as surface runoff, or via the groundwater (e.g., seeps; adits). Fine tailings material may also be present in the substrate of the waterways as a result of entrainment further upstream in the watershed. This material can serve as a secondary source of metals, mainly to the benthic invertebrate community.

The surface waters in mainstem Cement Creek and mainstem Mineral Creeks carry high loads of total and dissolved metals, and high acidity, into the Animas River in the vicinity of Silverton, even though substantial dilutions take place at that point. The benthic invertebrates and fish in the affected waterways become exposed to mine-derived and naturally-high levels of metals mainly by direct contact with surface water, sediment or pore water, whereas the wildlife receptors foraging in the Animas River become exposed by ingesting surface water and sediment, consuming fish, aquatic invertebrates, or plants. The current metal levels are high enough, and pH levels low enough, to cause mainstem Cement Creek and mainstem Mineral Creek to be essentially devoid of aquatic life, and to potentially affect aquatic life in the Animas River at and below Silverton.

3.0 COPEC SELECTION & BASELINE ECOLOGICAL EFFECTS EVALUATION

3.1 Matrices of concern

This BERA uses the analytical data from samples of surface water, sediment, pore water, and benthic invertebrates to assess current exposures to aquatic, community-level receptors and wildlife receptors.

3.2 Total metals versus dissolved metals

The surface water data consist of both total metals (i.e., unfiltered) and dissolved metals (i.e., filtered), whereas the pore water data consist only of dissolved metals.

- With two exceptions, exposures of the aquatic, community-level receptors to surface water samples collected from mainstem Cement Creek, mainstem Mineral Creek and the three Animas River reaches are quantified using dissolved metals because these data represent the fraction which is bioavailable, and hence toxic, to aquatic invertebrates and fish. The exceptions are Al and Fe in surface water, for which the chronic benchmark (Fe) or the hardness-dependent equation needed to derive a chronic benchmark (Al) are based on total recoverable metals (Colorado Department of Public Health and the Environment [CDPHE], 2013).

- Exposures of the benthic invertebrate community to pore water samples collected from the Animas River above mainstem Cement Creek, the Animas River below mainstem Mineral Creek, and in mainstem Mineral Creek are quantified using only dissolved metals, even for Al and Fe. The reason is that none of the pore water samples were analyzed for total metals. Additionally, none of the pore water samples were measured for pH. This variable is one of the two additional input parameters (the other one is hardness, which was available) required to derive a chronic benchmark for total Al using the CDPHE (2013) equation. As a result, the toxicity of Al in the pore water samples is determined by comparing dissolved Al levels to the standard chronic Al benchmark of 87 µg/L.

- The wildlife exposures associated with ingesting surface water from the Animas River were quantified using total metals concentrations. The reason is that the full amount of metal in water ingested while drinking becomes part of the daily dose of a wildlife receptor.

These different approaches ensure that the exposure of each receptor group to surface water is properly accounted for to the best ability of the available data.

3.3 Toxicity benchmarks

3.3.1 Surface water benchmarks

The metals concentrations measured in surface water and pore water samples are compared to surface water screening benchmarks to select COPECs for the aquatic, community-level receptors. The Colorado State Water Quality Criteria (WQC) regulation (CDPHE, 2013) is the primary source of surface water benchmarks used in the evaluation.

The metal concentrations are compared to the chronic WQC (referred to as the Criteria Continuous Concentration [CCC]). The WQC for Al, Ag, Cd, Cr, Cu, Mn, Pb, Ni, and Zn were adjusted for hardness in order to calculate hardness-specific benchmarks. Chronic toxicity thresholds summarized by Buchman (2008) are also used when Colorado State WQC are not available.

Table 3.1 summarizes the chronic surface water benchmarks and hardness-dependent equations used to select the surface water COPECs for aquatic, community-level receptors and for use in the subsequent risk evaluation.

3.3.2 Sediment benchmarks

The metal concentrations measured in bulk sediment samples collected from the Site are compared to no effect sediment benchmarks, to select COPECs for the benthic invertebrate receptors. The Threshold Effect Concentrations (TECs), which consist of the Threshold Effect Level (TEL), the TEL for *Hyalella azteca* in 28-day tests (TEL-HA28), the Effect Range-Low (ER-L) and the Lowest Effect Level (LEL), are the sources of sediment benchmarks used in COPEC selection.

The following hierarchy (in order of preference) was used to obtain these no-effect sediment benchmarks:

- MacDonald *et al.* (2000); consensus-based TECs,
- Ingersoll *et al.* (1996); TELs,
- Long *et al.* (1995); ER-Ls, and
- Thompson *et al*. (2005); LELs.

The Long et al. (1995) reference is included, even though its benchmarks pertain specifically to estuarine and marine environments. The reason is that this reference is the only one that provides a sediment benchmark for Ag.

In addition, following the COPEC selection process, the metals in sediment are further evaluated using effect sediment benchmarks, which consisted of Probable Effect Concentrations (PECs), the Probable Effect Level (PEL), the Effect Range-Median (ER-M), and the Severe Effect Level (SEL).

The following hierarchy (in order of preference) is used to obtain these effect sediment benchmarks:

- MacDonald *et al.* (2000); consensus-based PECs,
- Ingersoll *et al.* (1996); PELs,
- Long *et al.* (1995); ER-Ms, and
- Thompson *et al.* (2005); SELs.

Table 3.1 summarizes the no-effect sediment benchmarks used to select the sediment COPECs for benthic invertebrates and the effect sediment benchmarks that are also used in the subsequent risk evaluation. The shaded values represent the sediment benchmarks retained for these purposes.

3.4 TRVs for wildlife receptors

The following hierarchy was used to obtain the mammalian and avian no effect TRVs for comparison to the EDDs in the wildlife risk characterization:

- EPA Eco SSLs (http://www.epa.gov/ecotox/ecossl/).

- Sample *et al.*, 1996, Toxicological Benchmarks for Wildlife: 1996 Revision, ES/ER/TM-86/R3, http://www.esd.ornl.gov/programs/ecorisk/documents/tm86r3.pdf (values represent the test species).

Effect TRVs for birds and mammals are obtained from Table C-8 in Appendix C (available at www.epa.gov/reg3hscd/npl/PASFN0305521/fsr/All_Appendix_C.pdf) of the May 2011 *Final Remedial Investigation and Feasibility Study for the Lower Darby Creek Area (LDCA) Site, Delaware and Philadelphia Counties, Pennsylvania*.

Tables 3.2 and 3.3 present the no-effect and effect TRVs for birds and mammals, respectively. These two tables provide TRVs only for those metals identified as "important bioaccumulative compounds" in Table 4-2 of EPA (2000).

3.5 COPEC selection process

The surface water and sediment COPECs are presented in the next subsections. Ca, Mg, K, and Na were automatically eliminated as COPECs for aquatic community receptors and wildlife receptors because these four compounds represent essential physiological electrolytes that are not expected to cause toxicity at prevailing concentrations (EPA, 2001).

The surface water samples collected during the three flow periods (i.e., pre-runoff period [February to April], runoff period [May and June], and post-runoff period [July through

November]) were combined into one dataset for each of the five EUs. Hence, COPECs are selected for individual EUs across the three flow periods. This approach is conservative because the highest concentrations measured during the pre-runoff, runoff, and post-runoff periods are used to select the COPECs that would apply to all three flow periods.

3.5.1 Surface water COPECs for aquatic community-level receptors

The surface water COPEC selection process for aquatic community-level receptors evaluates the metals in two ways, depending on whether the toxicity of a metal is hardness-independent or hardness-dependent, as follows:

- Hardness-independent surface water toxicity

The toxicity of As, Be, Fe, and Se in surface water does not depend on hardness. COPEC selection for these four compounds consists of comparing maximum dissolved (As, Be, and Se) or total (Fe) metal concentrations measured in surface water samples to the published chronic surface water screening benchmarks.

- Hardness-dependent surface water toxicity

CDPHE (2013) states that the toxicity of Ag, Al, Cd, Cr, Cu, Mn, Ni, Pb, and Zn depend on surface water hardness (in addition to pH for Al; see CDPHE, 2013 for details). It would have been inaccurate to automatically select the highest concentration of each of these metals to select surface water COPECs because a lesser concentration could be more toxic if the hardness is much lower.

Under those circumstances, the only reliable way to identify the most toxic surface water concentration is to: (1) calculate hardness-adjusted HQs for each target metal in each surface water sample (note: A hardness-adjusted HQ is obtained by dividing a metal concentration by its toxicity benchmark adjusted for the hardness of the water sample associated with that metal), (2) identify the highest HQ for a target metal in all of the surface water samples, and (3) select the metal concentration associated with that HQ as the concentration for use in COPEC selection.

This approach ensures that the metal concentration associated with the highest HQ is used in the surface water COPEC selection process. **Appendix 7** summarizes the hardness-adjusted HQs for the hardness-dependent metals measured in the surface water samples.

Surface water COPECs for mainstem Mineral Creek

Mainstem Mineral Creek was sampled at one location (M34), for the purpose of this BERA. Twenty-four surface water samples were collected between May 2009 and September 2014. **Table 3.4** summarizes the COPEC selection process at this EU.

- As, Cr, Cu, Pb, Mn, Ni, and Se are eliminated because their maximum concentrations do not exceed their respective chronic surface water benchmarks.
- pH, Al, Be, Cd, Fe, Ag, and Zn are retained as COPECs for further evaluation because the concentrations associated with the highest HQs exceed their respective chronic surface water benchmarks.

Be is retained as a COPEC even though it is not present above its analytical DL in any of the surface water samples collected from this EU. It is flagged because half of the highest DL exceeds the chronic surface water benchmark. This analyte is discussed as an uncertainty in the risk characterization because it cannot be further evaluated quantitatively.

Surface water COPECs for mainstem Cement Creek

Mainstem Cement Creek was sampled at two locations (i.e., CC48 and CC49) for the purpose of this BERA. However, except for a single sample collected at CC49 in October of 2012, all the remaining surface water samples were collected from CC48 between May 2009 and September 2014. **Table 3.5** summarizes the COPEC-selection process at this EU.

- As, Cr, Ni, and Se are eliminated because the maximum concentrations do not exceed the respective chronic surface water benchmarks.
- pH, Al, Be, Cd, Cu, Fe, Pb, Mn, Ag, and Zn are retained as COPECs for further evaluation because the concentrations associated with the highest HQs exceed the respective chronic surface water benchmarks.

Ag is retained as a COPEC even though it is not present above its analytical DL in any of the surface water samples collected from this EU. It is flagged as a COPEC because half of the highest DL exceed its chronic surface water benchmark. This analyte is discussed as an uncertainty in the risk characterization because it cannot be further evaluated quantitatively.

Surface water COPECs for the Animas River above mainstem Cement Creek

This reach of the Animas River was sampled at six locations between May 2009 and September 2014. However, over half of the samples were collected at sampling location A68. **Table 3.6** summarizes the COPEC selection process at this EU.

- As, Cr, Ni, and Se are eliminated because the maximum concentrations do not exceed the respective chronic surface water benchmarks.

- pH, Al, Be, Cd, Cu, Fe, Pb, Mn, Ag, and Zn are retained as COPECs for further evaluation because the concentrations associated with the highest HQs exceed the respective chronic surface water benchmarks.

Be and Ag are retained as COPECs even though neither analyte is present above the analytical DL in any of the surface water samples collected from this EU. They are flagged because half of the highest DLs exceed their chronic surface water benchmarks. Both analytes are discussed as uncertainties in the risk characterization because they cannot be further evaluated quantitatively.

Surface water COPECs for the Animas River between mainstem Cement Creek and mainstem Mineral Creek

This reach of the Animas River was sampled only once at two locations in October of 2012. **Table 3.7** summarizes the COPEC selection process at this EU.

- As, Cr, Pb, Ni, Se, and Ag are eliminated because the maximum concentrations do not exceed the respective chronic surface water benchmarks.

- pH, Al, Be, Cd, Cu, Fe, Mn, and Zn are retained as COPECs for further evaluation because the concentrations associated with the highest HQs exceed the respective chronic surface water benchmarks.

Be is retained as a COPEC even though it is not present above its analytical DL in either of the two surface water samples collected from this EU. It is flagged because half of the highest DL exceeds the chronic surface water benchmark. This analyte is discussed as an uncertainty in the risk characterization because it cannot be further evaluated quantitatively.

Surface water COPECs for the Animas River below mainstem Mineral Creek

This reach of the Animas River was sampled at seven locations between May 2009 and September 2014. However, about half of the samples came from sampling location A72. **Table 3.8** summarizes the COPEC-selection process at this EU.

- As, Cr, Pb, Ni, and Se are eliminated because the maximum concentrations do not exceed the respective chronic surface water benchmarks.

- pH, Al, Be, Cd, Cu, Fe, Mn, Ag, and Zn are retained as COPECs for further evaluation because the concentrations associated with the highest HQs exceed the respective chronic surface water benchmarks.

Be and Ag are retained as COPECs even though neither analyte is present above its DL in any of the surface water samples collected from this EU. They are flagged because half of the highest

DL exceeds the chronic surface water benchmarks. Both analytes are discussed as an uncertainty in the risk characterization, but cannot be further evaluated quantitatively.

Table 3.9 summarizes all of the surface water COPECs for the aquatic, community-level receptors in mainstem Cement Creek, mainstem Mineral Creek, and the three reaches of the Animas River retained for further evaluation.

3.5.2 Sediment COPECs for benthic invertebrates

The sediment COPEC selection process for benthic community-level receptors is based on comparing maximum concentrations measured in bulk sediment samples collected from mainstem Mineral Creek, mainstem Cement Creek, and two of the three reaches of the Animas River against the no-effect sediment benchmarks identified in **Table 3.1**. Note that no sediment samples were collected from the Animas River flowing between mainstem Cement and Mineral Creeks. The sediment data from the Animas River are combined by reach to select the COPECs.

Sediment COPECs for mainstem Mineral Creek

This waterway was sampled twice for sediment in October 2012 and September 2014 at sampling location CC49. **Table 3.10** summarizes the COPEC selection process at this EU.

- Cr, Fe, Hg, Ni, and Ag are eliminated from further consideration because the maximum concentrations do not exceed the respective sediment screening benchmarks.
- Al, As, Cd, Cu, Pb, Mn, Se, and Zn are retained as COPECs for further evaluation because the maximum concentrations exceed the respective sediment screening benchmarks.

Be is retained as a COPEC even though it is not present above its analytical DL in the sediment sample collected from this EU. This analyte is flagged as a COPEC because it lacks a screening benchmark. It is as an uncertainty in the risk characterization, but cannot be further evaluated quantitatively.

Sediment COPECs for mainstem Cement Creek

This waterway was sampled once for sediment in October 2012 at sampling location CC49. **Table 3.11** summarizes the COPEC selection process at this EU.

- Al, Cd, Cr, Fe, Mn, Hg, Ni, and Se are eliminated from further consideration because the maximum concentrations do not exceed the respective sediment screening benchmarks.
- As, Cu, Pb, Ag, and Zn are retained as COPECs for further evaluation because the maximum concentrations exceed the respective sediment screening benchmarks.

Be is retained as a COPEC even though it is not present above its analytical DL in the sediment sample collected from this EU. This analyte is flagged as a COPEC because it lacks a screening benchmark. It is discussed as an uncertainty in the risk characterization, but cannot be further evaluated quantitatively.

Sediment COPECs for the Animas River above mainstem Cement Creek

This reach of the Animas River was sampled at six locations between May 2012 and September 2014. **Table 3.12** summarizes the COPEC selection process at this EU.

- Al, Cr, Fe, and Ni are eliminated as COPECs because the maximum concentrations fall below the screening benchmarks.

- As, Cd, Cu, Pb, Mn, Mercury (Hg), Se, Ag, and Zn are retained as COPECs because the maximum concentrations exceed the screening benchmarks.

Be is also retained as COPECs because it lacks a screening benchmark. This analyte is discussed as an uncertainty in the risk characterization, but cannot be further evaluated quantitatively.

Sediment COPECs for the Animas River below mainstem Mineral Creek

This reach of the Animas River was sampled at six locations between May 2012 and September 2014. **Table 3.13** summarizes the COPEC selection process at this EU.

- Cr, Fe, and Hg are eliminated as COPECs because the maximum concentrations fall below the screening benchmarks.

- Al, As, Cd, Cu, Pb, Mn, Ni, Se, Ag, and Zn are retained as COPECs because the maximum concentrations exceed the screening benchmarks.

Be is also retained as a COPEC because it lacks a screening benchmark. This analyte is discussed as an uncertainty in the risk characterization, but cannot be further evaluated quantitatively.

Table 3.14 summarizes all of the sediment COPECs for the benthic invertebrate community in mainstem Cement Creek, mainstem Mineral Creek, and the three reaches of the Animas River that were retained for further evaluation.

3.5.3 Pore water COPECs for benthic invertebrates

Similar to surface water, the pore water COPEC selection process evaluates the metals in two ways, depending on whether the toxicity of a metal is hardness-independent or hardness-dependent, as follows:

- Hardness-independent metals

The toxicity of As, Be, Fe, and Se in pore water does not depend on hardness. Pore water COPEC selection for these four compounds consists of comparing maximum dissolved metal concentrations measured in the pore water samples to chronic surface water screening benchmarks.

- Hardness-dependent metals

CDPHE (2013) states that the toxicity of Ag, Al, Cd, Cr, Cu, Mn, Ni, Pb, and Zn in water depends on surface water hardness (in addition to pH for Al; see CDPHE, 2013 for details. Note, however, that pH was not measured in the pore water samples and that the COPEC selection process for Al is therefore based on comparing dissolved Al concentrations against the standard Al chronic surface water benchmark of 87 µg/L). It would have been inaccurate to automatically retain the highest concentration of each of these metals to select pore water COPECs because a lesser concentration could be more toxic if the hardness was much lower.

Under those circumstances, the only reliable way to identify the most toxic pore water concentration is to: (1) calculate hardness-adjusted HQs for each target metal in each pore water sample, (2) identify the highest HQ for a target metal in all of the pore water samples, and (3) select the metal concentration associated with that HQ as the concentration to select pore water COPECs.

This approach ensures that the metal concentration associated with the highest HQ are used in the pore water COPEC selection process. **Appendix 8** summarizes the hardness-adjusted HQs for the hardness-dependent metals measured in the pore water samples. Pore water COPECs were identified for the Animas River above mainstem Cement Creek, the Animas River below mainstem Mineral Creek, and mainstem Mineral Creek. Pore water samples were not collected from the Animas River flowing between mainstem Cement and Mineral Creeks, or from mainstem Cement Creeks.

Pore water COPECs for the Animas River above mainstem Cement Creek

This reach of the Animas River was sampled at up to six locations in April 2014 and September 2014. **Table 3.15** summarizes the COPEC selection process at this EU.

- As, Cr, Fe, and Ni are eliminated as COPECs because the maximum concentrations fall below the screening benchmarks.

- Al, Be, Cd, Cu, Pb, Mn, Se, Ag, and Zn are retained as COPECs because the concentrations associated with the highest HQs exceed the screening benchmarks.

Be, Se, and Ag are retained as COPECs even though they are not present above their DLs in any of the pore water samples collected from this EU. They are flagged because half of the highest DL exceed the chronic surface water benchmarks. These three analytes are discussed as an uncertainty in the risk characterization, but cannot be further evaluated quantitatively.

Pore water COPECs for the Animas River below mainstem Mineral Creek

This reach of the Animas River was sampled at up to five locations in April 2014 and September 2014. **Table 3.16** summarizes the COPEC selection process at this EU.

- As, Cr, Cu, Pb, Ni, and Se are eliminated as COPECs because the concentrations associated with the highest HQs fall below the screening benchmarks.

- Al, Be, Cd, Fe, Mn, Ag, and Zn are retained as COPECs because their maximum concentrations exceed the screening benchmarks.

Be and Ag are retained as COPECs even though they are not present above the DLs in any of the nine pore water samples collected from this reach. They are flagged because half of the highest DLs exceed the chronic surface water benchmarks. These two analytes are discussed as an uncertainty in the risk characterization, but cannot be further evaluated quantitatively.

Pore water COPECs for mainstem Mineral Creek

Mainstem Mineral Creek was sampled once in September 2014. **Table 3.17** summarizes the COPEC selection process at this EU.

- Al, As, Cd, Cr, Cu, Fe, Pb, Mn, Ni, Se and Zn are eliminated as COPECs because the maximum concentrations fall below the screening benchmarks.

- Be and Ag are retained as COPECs because the maximum concentrations exceed the screening benchmarks.

Be and Ag are retained as COPECs even though they are not present above the DLs in the one pore water sample collected from this EU. They are flagged because half the DLs exceed the chronic surface water benchmarks. These two analytes are discussed as an uncertainty in the risk characterization, but cannot be further evaluated quantitatively.

Table 3.18 summarizes all of the pore water COPECs for the benthic invertebrate community in mainstem Mineral Creek, and the Animas River above mainstem Cement Creek and below mainstem Mineral Creek retained for further evaluation.

3.5.4 COPECs for wildlife receptors

The approaches outlined above does not apply to the four wildlife receptors evaluated using food chain modeling. The reason is that the exposures are not from direct contact with surface water or sediment, but from ingesting surface water, sediment, and aquatic food items. Therefore, a metal was automatically retained as a wildlife COPEC for evaluation in the food chain models if it met the following two conditions: 1) it was present above its analytical DL in at least one surface water sample or one sediment sample, and 2) it was identified as an "important bioaccumulative compound" in Table 4-2 in EPA, 2000. *Bioaccumulation testing and interpretation for the purpose of sediment quality assessment, Status and needs.* EPA-823-R-00-001, February 2000. Metals that fall into the bioaccumulative category consist of As, Cd, Hexavalent Chromium (CrVI), Cu, Pb, methylmercury (MeHg), Ni, Se, Ag, and Zn. Note that CrVI and MeHg are not expected to be present in surface water and sediment from the Animas River. However, as a conservative measure, oxidized Cr (i.e., CrIII) and inorganic Hg, if detected, are retained for evaluation in the wildlife food chain models.

3.6 Toxicity testing

3.6.1 Surface water

EPA Region 8 performed three sets of surface water toxicity tests in October 2012, November 2012, and April 2013 at the Golden, CO laboratory. These tests consisted of exposing juvenile rainbow trout (*Oncorhynchus mykiss*) for 96 hours at 12°C to undiluted samples from the Animas River, mainstem Cement Creek, and mainstem Mineral Creek, and to various dilutions. **Appendices 9.a and 9.b** provide more details on the study design and rationale.

3.6.1.1 Surface Water Collection and dilutions

October 2012

<u>Site-specific toxicity testing</u>:

Surface water samples were collected in October 2012 from six sampling locations, as follows (see **Figure 1.1 and 1.2**):

- *Animas River above mainstem Cement Creek*: sampling locations A56 ("upstream") and A68.

- *Animas River below mainstem Mineral Creek*: sampling locations A72, A73B, A75B, and BBridge.

These surface water samples represented composites collected in the mid-water column across the width of the Animas River. They were tested undiluted for acute toxicity.

Serial dilution toxicity testing:

Flow-weighted surface water samples were also collected from mainstem Mineral Creek (sampling location M34) and mainstem Cement Creek (sampling location CC48). The samples were, (a) combined in a 61% (M34) + 39% (CC48) ratio (M34/CC48), (b) diluted using water from "upstream" sampling location A56 to generate water representing 6.25%, 12.5%, 25%, 50% and 100% CC48/M34, and (c) tested for acute toxicity.

Finally, the flow-weighted M34/CC48 surface water sample was diluted using water from sampling locations A68 to generate water representing 6.25%, 12.5%, 25%, and 50% M34/CC48 samples and then tested for acute toxicity.

November 2012

Surface water samples were collected in November 2012 from four sampling locations, as follows:

- *Animas River above mainstem Cement Creek*: sampling location A68
- *Animas River below mainstem Mineral Creek*: sampling location A72
- *Mainstem Cement Creek*: sampling location CC48
- *Mainstem Mineral Creek*: sampling location M34

All these surface water samples represented composite samples collected in the mid-water column across the width of each of the waterways.

Site-specific toxicity testing

Surface water from sampling locations M34, A68 and A72 were tested undiluted for acute toxicity.

Serial dilution testing

Surface water from sampling location A68 was used as a diluent to generate dilutions of surface water from sampling locations A72, as follows: 0% (full strength A68 water), 5%, 10%, 25%, 50%, 75%, and 100% (full strength A72 water). Each of these dilutions was then tested for acute toxicity.

Surface water from sampling location A68 was used as a diluent to generate dilutions of surface water collected from sampling location CC48, as follows: 0% (full strength A68), 1%, 3%, 6%, 12%, 25%, and 50% (50% CC48 water). Each of these dilutions was then tested for acute toxicity.

Surface water from sampling location A68 was used as a diluent to generate dilutions of a flow-weighted mixture of water samples collected from M34 and CC48 (M34/CC48), as follows: 0% (full strength A68 water), 4%, 9%, 20%, 40%, 65%, and 85% (85% of M34/CC48 flow-weighted mixture water). Each of these dilutions was then tested for acute toxicity.

April 2013

<u>Site-specific toxicity testing:</u>

Surface water samples were collected in April 2013 from six sampling locations, as follows:

- *Animas River above mainstem Cement Creek*: sampling location A68

- *Animas River below mainstem Mineral Creek*: sampling locations A72, A73, A73B, and A75B

- *Mainstem Mineral Creek*: sampling location M34

All these surface water samples represented composite samples collected in the mid-water column across the width of each waterway. They were tested full-strength (i.e., undiluted) for acute toxicity.

<u>Serial dilution toxicity testing</u>

Animas River water (A72) diluted by Hard Reconstituted Water (HRW)

The surface water sample collected from sampling location A72 was serially diluted with HRW to determine what dilutions of site water would cause acute toxicity to juvenile rainbow trout. The serial dilutions resulted in Animas River A72 surface water samples of 12%, 25%, 35%, 50%, 75%, and 88% strength.

Combined Mineral Creek and Cement Creek water (M34/CC48) diluted by A68 and HRW

The flow-weighted mixed surface water sample M34/CC48 was serially diluted either with Animas River water collected at sampling location A68 or with HRW to determine what dilutions would cause acute toxicity to juvenile rainbow trout. The serial dilutions resulted in M34/CC48 samples of 25%, 50%, 75%, 80%, 90%, and 95% strength (using water from sampling location A68 as diluent) or 25%, 50%, 75%, 90%, and 95% strength (using HRW as diluent).

3.6.1.2 Interpretation of the surface water toxicity test results

October 2012

Table 3.19 summarizes the outcome of the October 2012 toxicity tests.

Site-specific acute toxicity testing:

100% of the juvenile rainbow trout exposed for 96 hours to undiluted Animas River water survived at sampling locations A56 ("upstream" location), A68, A73B, A75B, and BBridge. On the other hand, complete mortality was observed in juvenile rainbow trout exposed for 96 hours to undiluted Animas River water collected from A72.

These results showed that at least 3,500 ft of the Animas River below mainstem Mineral Creek up to sample location A72 was acutely toxic to juvenile rainbow trout in October of 2012. Sampling location A73B, situated about 5.9 miles downstream from sampling location A72, was not acutely toxic during that same period. This finding showed that ongoing dilution of the Animas River with surface water from various drainages flowing into the Animas River downstream of sampling location A72 mitigated the acute toxicity to juvenile rainbow trout during this sampling period.

Serial dilution acute toxicity testing

A flow-weighted sample of M34/CC48 was serially diluted either with surface water collected from sampling location A56 ("upstream" location) or from sampling location A68. The results showed that the M34/CC48 mixture was acutely toxic to juvenile rainbow trout only when it was tested undiluted (acute mortality was not significant when the M34/CC48 mixture was diluted 50% with A56 water). The M34/CC48 mixture was also acutely toxic when it was diluted 50% with A68 water.

November 2012

Table 3.20 summarizes the outcome of the November 2012 acute toxicity tests.

Site-specific acute toxicity testing:

Ninety-two and a half percent of the juvenile rainbow trout survived a 96-hour exposure to undiluted Animas River water collected from sampling location A68. On the other hand, all juvenile rainbow trout died after 96 hours of exposure to surface water collected from sampling location M34 on mainstem Mineral Creek. Additionally, only 2.5% of juvenile rainbow trout survived a 96-hour exposure to surface water collected from sampling location A72 on the Animas River about 3,500 ft below mainstem Mineral Creek.

These results showed that surface water from mainstem Mineral Creek and from the Animas River down to at least sampling location A72 was acutely toxic to juvenile rainbow trout in November of 2012. The testing structure did not allow for an estimation of how much further downstream from A72 this acute toxicity would be expressed. However, the serial dilution of surface water from sampling location A72 with surface water from sampling location A68 (see below) showed that this water was not acutely toxic to juvenile rainbow trout when tested at a strength of 75%. This evidence suggested that a relatively small amount of dilution of the Animas River surface water with uncontaminated water further downstream would be expected to mitigate the acute toxicity measured at sampling location A72.

Serial dilution acute toxicity testing

Surface water collected from sampling location A72 was serially diluted with surface water collected further upstream on the Animas River at sampling location A68. Survival of juvenile rainbow trout acutely exposed to the surface water sample collected at A72 was not significantly different from the control when that sample was at 75% strength. Only undiluted A72 sample resulted in acute toxicity.

Surface water from sampling location CC48 resulted in 100% mortality when it was diluted 50% using water from sampling location A68 as the diluent. The CC48 surface water had to be diluted by a factor of four using A68 water as the diluent in order to mitigate the acutely toxic effects.

A similar pattern was observed using the flow-weighted M34/CC48 sample. This sample at 40% strength, using surface water from sampling location A68 as the diluent, was not acutely toxic to juvenile rainbow trout, whereas mortality was 100% when the M34/CC48 sample was tested at 65% strength using the same diluent source.

April 2013

Table 3.21 summarizes the outcome of the April 2013 acute toxicity tests.

Site-specific acute toxicity testing:

Survival in juvenile rainbow trout exposed to Animas River surface water from sampling locations A73 (98%), A73B (97.5%), and A75B (100%) was not significantly different from the controls. On the other hand, survival was significantly reduced in Animas River surface water

from sampling location A68 (67.5% survival) and A72 (0% survival), and in mainstem Mineral Creek from location M34 (15% survival).

These results showed that at least 3,500 ft of the Animas River below mainstem Mineral Creek was acutely toxic to juvenile rainbow trout in April of 2013. Sampling location A73, situated about 5.9 miles downstream from sampling location A72, was not acutely toxic during that same period. This finding showed that ongoing dilution of the Animas River with surface water from various gulches and creeks flowing into the Animas River downstream of sampling location A72 mitigated the acute toxicity to juvenile rainbow trout.

<u>Serial dilution acute toxicity testing</u>:

Survival in juvenile rainbow trout exposed for 96 hours to Animas River surface water from sampling location A72 was not affected up to sample strength of 88% when HRW was used as the diluent. The data suggested that a relatively small amount of dilution with uncontaminated water removed the acute toxicity measured in full-strength surface water from sampling location A72. This conclusion is tempered by the fact that the diluent was not Animas River water collected upstream of the confluence with mainstem Mineral Creek. Rather, HRW was used as the diluent, which may have affected the toxicity of the hardness-dependent metals present in the A72 sample.

Seasonal patterns in acute toxicity to juvenile rainbow trout

Table 3.22 summarizes survival in juvenile rainbow trout acutely exposed to undiluted surface water samples in October 2012, November 2012, and April 2013.

The patterns can be interpreted as follows:

- Sample location A68 is upstream of the confluence with mainstem Cement Creek. Acute toxicity to juvenile rainbow trout was not present in surface water samples collected from this location in October and November 2012, but was observed in April 2013. It is not known if the source of this toxicity originated at the Mayflower Mill or further upstream since surface water from sampling location A56 ("upstream" location) was not tested for acute toxicity in April 2013.

- The surface water samples collected from sampling location A72 in October 2012, November 2012, and April 2013 were uniformly acutely toxic to juvenile rainbow trout. This toxicity most likely originated from mainstem Cement Creek and mainstem Mineral Creek, both of which independently showed severe acute toxicity in November 2012 and April 2013.

- The test data showed that acute toxicity to juvenile rainbow trout was consistently present at sampling location A72 (i.e., about 3,500 ft below the confluence with mainstem Mineral Creek) but was consistently absent at sampling locations A73/A73B (i.e., about 5.9 miles downstream).

3.6.2 Sediment toxicity testing

Two sediment toxicity tests were performed in December 2012 and November 2014 at the EPA regional laboratory in Golden, CO. The tests consisted of exposing juvenile amphipods (*Hyalella azteca*) for ten days at 23°C to sediment samples collected from the Animas River (A56 ["upstream" location], A60, A68, A72, A73, A73B, A75D, A75B, and BBridge), mainstem Cement Creek (CC49), and mainstem Mineral Creek (M34). The test endpoints consisted of survival and biomass. **Appendices 10.a and 10.b** provide details on the study design and rationale.

"Biomass" was defined as the total dw of the surviving organisms across replicates in a sediment sample at the end of the test divided by the number of organisms introduced in that sample at the start of the test. This measure was sensitive to mortality because death reduces the number of remaining organisms, which thereby decreases the final combined weight of the survivors at the end of the test, even if the individual survivors maintained or gained weight.

Table 3.23 provides the results of the two sediment toxicity tests. Note that the responses measured in both tests were compared to the laboratory control sample, instead of a Site-specific reference sample. The reason is that the sediment collected in the Animas River upstream of location A60 for use as a reference (i.e., at location A56) showed severe effects and therefore did not represent unimpacted conditions. The results of the two tests can be summarized as follows:

- The laboratory control samples in the December 2012 and November 2014 tests showed 97.5% and 92.5% survival, respectively, with measureable growth in both tests. These responses met the two test acceptability criteria, namely over 80% survival plus measureable growth after ten days of exposure. Hence, the results of both tests were acceptable for use in decision making.

- Survival in the December 2012 test in sediment samples collected from locations A56, A68, A72, A73B, A75B, BBridge, CC49, and M34 were significantly lower compared to the laboratory control sample. Survival in the Animas River sediment samples during the November 2014 test was statistically lower than the laboratory control sample only at location A56 (note: CC49, M34, A73B, and A75B were not tested for toxicity in November 2014).

- Biomass in both the December 2012 and November 2014 tests was significantly lower at all sample locations compared to the laboratory control.

3.6.3 Benthic invertebrate survey

Macroinvertebrate samples were collected in September 2014 from seven EUs on the Animas River above mainstem Cement Creek (i.e., A56 ["upstream"], A60, and A68) and below mainstem Mineral Creek (i.e., A72, A73, A75D and BBridge). One sample each was also collected from the mouth of mainstem Cement Creek (i.e., CC49) and the mouth of mainstem Mineral Creek (i.e., M34). Note that additional benthic samples were collected from several other non-EU locations on the Animas River, including reference location A73EC (Elk Creek near the confluence with the Animas River [see **Figure 1.2**]), reference location A75 CC (Cascade Creek near the confluence with the Animas River [see **Fig. 1.2**]), and James Ranch, which is a sampling location on the Animas River downstream of Bakers Bridge. These data are included in the discussion below to provide a broader perspective.

Samples for Multi-Metric Index (MMI) analysis were collected by using a modified rectangular kick net and field samplers used their feet and hands to disturb and dislodge organisms from substrate in a one-square meter immediately upstream of the net for a 60-second collection interval. This collection method was used at all sampling locations and the technique followed similar protocol that was used in past monitoring efforts.

Additional benthic invertebrate samples were collected for metals tissue analysis at each of the sample locations listed in this section. Sampling for tissue samples followed similar procedures as described above with the exception of the timed interval for MMI analysis. For tissue analysis, the field sampler focused on taking additional time and adding additional preferred habitat areas in order to get the required amount of sample for metals analysis. Efforts were made to collect as many organisms as possible with the goal of collecting one gram of dw material for tissue residue analysis.

The benthic invertebrate samples were preserved with ethanol in the field for counting and identification and the additional benthic invertebrate samples for metals tissue analysis were placed on ice for transportation then stored in an ultra-low temperature freezer until analysis. The data were reported as 300-count subsamples (based on protocols for MMI calculation provided by CDPHE). **Appendix 11** provides the raw counts and summarizes the community data. A subset of the measures listed below are identified with an asterisk (*) and are provided in **Table 3.24** by sampling location.

- *MMI scores
- Total number of organisms (# per sample)
- *Number of taxa per sample
- *Shannon-Weaver Diversity (H')
- *Hilsenhoff Biotic Index (HBI)
- *Total # of Ephemeroptera, Plecoptera, Trichoptera (EPT) taxa
- *EPT Index (% of total number of taxa)

- *Ephemeroptera abundance (% of total number)
- # of Ephemeroptera (mayflies) taxa
- # of Plecoptera (stoneflies) taxa
- # of Trichoptera (caddisflies) taxa
- *% EPT (% of total number)
- *# of intolerant taxa
- *Tolerant organisms (% of total number)
- Dominant taxon (% of total number)
- *Filterers (% of total number)
- *Scrapers (% of total number)
- # Clinger Taxa
- *Clingers (% of Total Number)

MMI scores

The Multi-Metric Index (MMI) bioassessment tool is composed of separate benthic invertebrate indices calibrated to respond to stressors affecting aquatic communities in one of three biotypes. A biotype is defined as an aggregation of macrobenthos sites that have similar general environmental attributes, such as elevation, stream slope, and ecoregion. The sampling locations on the Animas River of interest to this BERA fall into two biotypes, as follows:

- *Biotype 1 (Transition):* A75D, Bakers Bridge, James Ranch and A75CC (reference)

- *Biotype 2 (Mountain):* A56, A60, A68, A72, A73, M34, CC49, and A73EC (reference)

MMIs are calibrated specifically for each biotype. The MMI is composed of several metrics selected to represent categories of community characteristics, including richness, composition, functional feeding group, mode of locomotion, and pollution tolerance. The metrics were chosen for their ability to (a) discriminate between reference and stressed sites, (b) represent multiple metric categories, (c) be ecologically meaningful, and (d) not duplicate other metrics in the index.

The metrics included in the two biotypes are as follows:

- *Biotype 1 (Transition):* total taxa, predator-shredder taxa, clinger taxa, % Ephemeroptera, Beck's Biotic Index, Shannon Diversity Index, and Hilsendorf Biotic Index.

- Biotype 2 (Mountain): EP taxa, % Chironomidae, sensitive plains families, predator-shredder taxa, clinger taxa, % non-insect, Shannon Diversity Index, and Hilsendorf Biotic Index.

The MMI scores are compared against aquatic life thresholds which were obtained by analyzing the biological condition at selected reference sites in each of the biotypes. **Attachment 1** below represents the two biotypes for the Animas River and their associated thresholds for impairment of aquatic life use.

Attachment 1: Aquatic Life Use Thresholds			
Biotype		**Attainment Threshold**	**Impairment Threshold**
Biotype 1	Transition	52	42
Biotype 2	Mountains	50	42

In addition, the Hilsenhoff Biotic Index and the Shannon Diversity Index are used as auxiliary metrics that supplement the MMI for Class 1 waters with MMI scores between the attainment and impairment thresholds. A site is considered impaired if a Class 1 fails to meet the criteria shown in **Attachment 2** below for either auxiliary metric.

Attachment 2: Auxiliary Metric Thresholds for Class 1 Waters with MMI Scores Between the Attainment and Impairment Thresholds			
Biotype		**Hilsenhoff Biotic Index**	**Shannon Diversity Index**
1	Transition	<5.4	>2.4
2	Mountains	<5.1	>3.0

Shannon-Weaver Diversity Index (H')

The *Shannon-Weaver Diversity Index* determines species diversity. This index calculates the number of different species in a sample (species richness), and the proportion of individuals of a particular species compared to the number of individuals of other species in the sample. This comparison shows how rare or common a species is in a group. The index is calculated as follows:

$$H' = -\sum_{i=1}^{s} (P_i * \ln P_i)$$

where:

H' = the Shannon diversity index
P_i = fraction of the sample consisting of species i (i.e., the proportion of a species i relative to the total number of species present in a sample)
S = numbers of species present

A high H' represents a diverse and evenly-distributed community. A low H' represents a less diverse community. An H' of zero represents a community containing a single species.

The Hilsendorf Biotic Index (HBI)

The HBI estimates the overall tolerance of the community in a sample to organic pollution, weighted by the relative abundance of each taxonomic group. Species are assigned a tolerance value ranging between zero and ten, with zero for the most-sensitive species and ten for the least-sensitive species.

The HBI is calculated as follows:

$$HBI = \frac{\Sigma\, n_i \times a_i}{N}$$

where:

n = number of specimens in taxon i
a = tolerance value for taxon i
N = total number of specimens in the sample

The HBI increases with decreasing water quality. Note that the taxon-specific tolerance values used in the HBI calculations were originally developed to assess organic pollution, but that the Animas River system is impacted mainly by mining-related inorganic pollution.

EPT

The EPT-related measures pertain to the number of mayfly, stonefly, and caddisfly taxa present in a sample. The EPT species are considered sensitive to pollution. As a result, impacted waters typically have lower numbers of EPT taxa than pristine waters.

Intolerant taxa

The *intolerant taxa* represent species in a sample that are intolerant to the presence of pollution. The number of intolerant taxa typically decreases with increasing contamination.

Filterers, scrapers, and clingers

These measures estimate what fraction of benthic species in a sample is represented by filter-feeders, scrapers, and clingers.

Table 3.24 summarizes the macroinvertebrate community data collected in September 2014. These data are also plotted in **Figure 3.1**. **Appendix 20** provides the MMI scores associated with this sampling event. The discussion below focuses specifically on the Animas River and the following benthic invertebrate metrics: MMI scores, # of taxa, the Shannon-Weaver Diversity

Index, # of EPT taxa, the EPT index, the % EPT. Focusing the data interpretation on the EPT metrics is appropriate because the EPT species are considered highly sensitive to aquatic pollution.

- The **MMI score** (**Fig. 3.1a**) is highest at the two reference locations. The score shows impairment of aquatic life use at sampling locations A56 and A68 (but not A60) in the Animas River above mainstem Cement Creek. The score also shows impairment of aquatic life use at sampling locations A72, A73, and Bakers Bridge (but not A75D or James Ranch) in the Animas River below mainstem Mineral Creek.

- The **# of taxa** (**Fig. 3.1b**) is highest at the two reference locations. This metric drops, on average, in the Animas River above mainstem Cement Creek, and reaches its lowest level at sampling locations A72 and A73. The # of taxa further downstream from A73, and up to James Ranch, rebounds to the levels observed in the Animas River above mainstem Cement Creek but does not reach the levels measured at the two reference locations.

- The **Shannon-Weaver Diversity Index** (**Fig. 3.1c**) is high at the two reference locations. It stays high (except for location A56) in the Animas River above mainstem Cement Creek, and reaches its lowest level at sampling location A73. The metric further downstream from location A73, and up to James Ranch, rebounds to the levels observed in the Animas River above mainstem Cement Creek. However, except for location A75D, this metric in the Animas River below mainstem Mineral Creek does not reach the levels measured at the two reference locations.

- The **# of EPT taxa** (**Fig. 3.1b**) is highest at the two reference locations. This metric drops in the Animas River above mainstem Cement Creek, and reaches its lowest level at sampling location A72. The # of EPT taxa further downstream from A72, and up to James Ranch, rebounds back close to the levels observed in the Animas River above mainstem Cement Creek but does not reach the levels measured at the two reference locations.

- The **EPT Index** (which represents the # of EPT taxa as a % of the total # of taxa; **Fig. 3.1e**) is high in the two reference locations. It drops (except at location A56) in the Animas River above mainstem Cement Creek and reaches its lowest level at location A72. The metric further downstream from location A72, and up to James Ranch, remains low (except for location A73) and does not rebound to the levels observed in the Animas River above mainstem Cement Creek or the two reference locations.

- The **%EPT** (which represents the fraction of the total number of organisms consisting of EPT; **Fig. 3.1e**) is highest at the two reference locations. It drops sharply in the Animas River above mainstem Cement Creek and recovers in the Animas River below Mineral

creek but not (except at location A73) to the levels measured at the two reference locations.

The general pattern for the September 2014 benthic invertebrate survey shows a stressed benthic community in sections of the Animas River both above mainstem Cement Creek (between sampling locations A56 and A68) and below mainstem mineral Creek. The impacts of the contamination entering the Animas River from mainstem Cement and Mineral Creek are felt most strongly at sampling locations A72 and A73. The benthic invertebrate community starts recovering downstream of A73 and up to James Ranch but not to the levels typically observed at the two reference locations.

4.0 BASELINE EXPOSURE ESTIMATES

4.1 Introduction

The exposure analysis for this BERA consisted of the following two components: (a) quantify surface water, sediment, and pore water exposures to community-level receptors in mainstem Cement Creek, mainstem Mineral Creek, and the three Animas River reaches, and (b) perform wildlife exposure modeling in the Animas River above mainstem Cement Creek and below mainstem Mineral Creek to calculate RME and CTE EDDs (mg/kg.bw-day).

4.2 Aquatic EUs

This BERA identifies discrete aquatic EUs to summarize the sediment, surface water, and pore water analytical data, and to quantify exposures to aquatic, community-level and wildlife receptors. The aquatic EUs were defined as follows:

- *Mainstem Cement Creek* is assessed by combining data from two sampling locations:
    - Location CC48: situated about one mile upstream of the confluence with the Animas River in Silverton. This location was sampled numerous times for surface water between May 2009 and September 2014, but not for sediment or pore water.
    - Location CC49: situated between CC48 and the confluence with the Animas River in Silverton. This location was sampled once for sediment and once for surface water in October 2012, but not for pore water.
- *Mainstem Mineral Creek* is assessed at one sampling location, as follows:
    - Location M34 is situated in mainstem Mineral Creek less than a half of a mile above the confluence with the Animas River in Silverton. This location was sampled numerous times for surface water between May 2009 and September 2014, twice for sediment in October 2012 and September 2014, and once for pore water in September 2014.
- *The Animas River above mainstem Cement Creek*:

This reach covers about two miles of the Animas River between sampling locations A60 and A68. Location A56 is situated on the Animas River about a quarter mile upgradient from A68, above the Mayflower Mill and Arrastra Creek. This location is not part of the EU and is therefore not included in the exposure calculations. A56 represents "upstream" conditions reflective of other sources of contamination further upgradient in the watershed. Location A68 is about a quarter mile upstream of the confluence with Cement Creek.

This BERA assumes that exposure to benthic invertebrates, fish, and wildlife receptors is best represented by the chemical conditions measured across all of the sampling locations in this reach. Hence, all surface water, sediment, pore water, and benthic invertebrate tissue analytical data collected between A60 and A68 are combined into one EU.

- *The Animas River between mainstem Cement Creek and mainstem Mineral Creek*

This reach covers about one mile of the Animas River across from Silverton. Location A69A is about 2,500 ft downstream of the confluence with Cement Creek, whereas location A70B is just upstream of the confluence with Mineral Creek.

Only one surface water sample and no sediment samples were collected from each of these two sampling locations. Exposure to wildlife receptors could not be evaluated in this reach of the Animas River because sediment analytical data are not available to estimate the contaminant levels in the food items for evaluation in the food chain models.

- *The Animas River below mainstem Mineral Creek*

This reach covers about 30 river-miles between sampling locations A71B and BBridge. Location A71B is immediately downstream of the confluence with Mineral Creek.

This BERA assumes that exposure via surface water, sediment, and pore water to benthic invertebrates and fish in this reach of the Animas River is best represented by the chemical conditions measured at each separate sampling location. Hence, each sampling location represents its own EU for the community-level receptors. The same assumption is used to calculate exposures to the wildlife receptors. The reason is that the distance between many of the sampling locations is too great to assume that any of the receptor groups would be continuously exposed across these locations.

4.3 Seasonal effects

Surface water samples were collected throughout the year between May 2009 and September 2014 to investigate differences in metal loads across seasons. The surface water exposures for the aquatic community-level receptors were calculated at each of the sampling locations for three specific hydrologicperiods across years, as follows:

- *Pre-runoff period*: February, March, and April (2010, 2011, and 2014 data combined),

- *Runoff period*: May and June (2009, 2010, 2011, 2013, and 2014 data combined), and

- *Post-runoff period*: July, August, September, October, and November (2009, 2010, 2011,

2012, and 2014 data combined). No surface water samples were collected in the months of December or January.

This approach ensures that the surface water exposures reflect the seasonal differences that exist in metal concentrations in the three waterways during the 2009 to 2014 time period.

The surface water exposures for the wildlife receptors were calculated at each EU across the three runoff periods.

4.4 Exposure point concentrations

The EPCs used in the exposure calculations consist of RMEs and CTEs for metals in surface water, sediment, and pore water. Depending on the structure of a dataset, the RMEs represent either 95% Upper Confidence Limits (UCLs) derived using the ProUCL software, or the maximum detected values if UCLs could not be calculated due to limited datasets. If a data set was big enough to calculate 95% UCLs, but one or more of the UCLs exceeded their maximum concentrations, then the maximum concentration is used in the exposure calculations. All the CTEs represent arithmetic means, including half of the DL for non-detected compounds. Only the metals identified as COPECs in Section 3 are used to calculate EPCs.

Appendix 12 provides the ProUCL outputs (data permitting) for hardness and dissolved metals in surface water to derive EPCs for aquatic, community-level receptors. **Appendix 13** provides the ProUCL outputs for total metals in surface water (data permitting) to derive EPCs for wildlife receptors in the Animas River above mainstem Cement Creek and below mainstem Mineral Creek. **Appendix 14** provides the ProUCL outputs for sediment (data permitting) to derive EPCs for benthic invertebrates and the wildlife receptors in the Animas River above mainstem Cement Creek and below mainstem Mineral Creek. **Appendix 15** provides the ProUCL outputs for the pore water samples collected from the Animas River above mainstem Cement Creek (note: not enough pore water samples were collected from the individual sampling locations on mainstem Mineral Creek or from the Animas River below mainstem Mineral Creek to run ProUCL).

The Animas River above mainstem Cement Creek, and between Cement Creek and Mineral Creek, is considered as two separate EUs to calculate EPCs for community-level, aquatic receptors and the four wildlife receptors. On the other hand, the six sampling locations on the Animas River below mainstem Mineral Creek are treated as separate EUs to calculate EPCs for both the community-level, aquatic receptors and the four wildlife receptors.

The concentrations of key surface water metals to this BERA (i.e., Al, Cd, Cu, Mn, Pb, and Zn) are also assessed on a sample-by-sample basis. These analytes are evaluated by calculating HQs

based on dividing the measured concentrations by the hardness-adjusted surface water benchmarks (see **Appendix 7**). The HQs are then plotted by analyte, sampling location, and hydrologic period to create "scatter plots" which provide a visual overview of spatial and temporal changes in surface water risk. The results of this evaluation are further discussed in Section 5.

4.4.1 Aquatic community-level receptors

The aquatic, community-level receptors are assumed to be directly exposed to surface water, sediment, and pore water in mainstem Cement Creek, mainstem Mineral Creek, the Animas River between mainstem Cement Creek and mainstem Mineral Creek, and at the individual sampling locations on the Animas River below mainstem Mineral Creek.

4.4.1.1 Surface water

The EPCs for dissolved metals in surface water are provided in **Table 4.1** (mainstem Mineral Creek), **Table 4.2** (mainstem Cement Creek), **Table 4.3** (Animas River above mainstem Cement Creek), and **Table 4.4** (Animas River between mainstem Cement and Mineral Creeks). Additionally, **Tables 4.5 to 4.11** provide the EPCs in surface water samples collected from sampling locations A71B, A72, A73, A73B, A75D, A75B, and BBridge on the Animas River below mainstem Mineral Creek. The EPCs for dissolved metals in surface water samples collected from the two reference locations (i.e., A73EC and A74CC) will be included in the final version of this BERA.

4.4.1.2 Sediment

The EPCs for metals in sediment samples are provided in **Table 4.12** (mainstem Mineral Creek), **Table 4.13** (mainstem Cement Creek), and **Table 4.14** (Animas River above mainstem Cement Creek). Additionally, **Tables 4.15 to 4.20** provide the EPCs for metals in sediment collected from sampling locations A72, A73, A73B, A75D, A75B, and BBridge on the Animas River below mainstem Mineral Creek. The EPCs for metals in sediment samples collected from the two reference locations (i.e., A73EC and A74CC) will be included in the final version of this BERA.

4.4.1.3 Pore water

The EPCs for dissolved metals in pore water samples are provided in **Table 4.21** (mainstem Mineral Creek), **Table 4.22** (Animas River above mainstem Cement Creek), and **Tables 4.23 to 4.27** for sampling locations A72, A73, A73B, A75D, and BBridge on the Animas River below mainstem Mineral Creek. The EPCs for dissolved metals in pore water samples collected from the two reference locations (i.e., A73EC and A74CC) will be included in the final version of this BERA.

4.4.2 Wildlife receptors

The four wildlife receptors are assumed to forage across the two miles of Animas River above mainstem Cement Creek and at each of the individual sampling locations on the Animas River below mainstem Mineral Creek. The Animas River reach flowing between mainstem Cement and Mineral Creeks is omitted from food chain modeling because no sediment data were available to derive tissue residues needed to calculate daily doses. The two creeks are also omitted because the SLERA showed that they cannot support a healthy forage base for use by wildlife receptors.

4.4.2.1 Surface water

The EPCs for total metals in surface water used for food chain modeling are provided in **Table 4.28** (Animas River above mainstem Cement Creek), and **Tables 4.29 to 4.34** that show the EPCs for total metals measured in surface water samples collected from sampling locations A72, A73, A73B, A75D, A75B, and BBridge on the Animas River below mainstem Mineral Creek.

4.4.2.2 Sediment

The EPCs for metals in sediment samples are provided in **Table 4.14** (Animas River above mainstem Cement Creek) and **Tables 4.15 to 4.20** that show the EPCs for metals measured in sediment collected from sampling locations A72, A73, A73B, A75D, A75B, and BBridge on the Animas River below mainstem Mineral Creek.

4.5 Wildlife food chain modeling

Section 2.4.2.2 presents the four wildlife receptors evaluated in this BERA using exposure modeling. These receptors are the American dipper (representing invertivorous birds), the mallard (representing omnivorous birds), the belted kingfisher (representing piscivorous birds), and the muskrat (representing herbivorous mammals).

Wildlife species are assumed to be exposed to COPECs in the Animas River by direct ingestion of surface water, incidental ingestion of sediment, and by feeding on contaminated food items that accumulated metals from the sediment. This BERA calculates total EDDs for each wildlife receptor to estimate their exposure using a standard exposure equation which incorporates species-specific natural history parameters.

Table 4.35 presents the intake equations for each wildlife receptor species. **Table 4.36** provides the species-specific exposure parameters (e.g., body weights, ingestion rates, relative consumption of food items, etc.), as well as the reference sources and assumptions on which these values were based. This BERA assumes two different diets for the omnivorous mallard: (a) 100% benthic invertebrates to model the diet of female mallards during the egg-laying period

(the "100% diet"), and (b) a half and half diet of benthic invertebrates and plants to model the diet of mallards for the rest of the year (the "50%-50% diet").

The exposure calculations assume that the target wildlife receptors consume aquatic invertebrates, aquatic plants, or fish, depending on the species. **Tables 4.37, 4.38 and 4.39** provide the literature-derived regression models and uptake factors used to estimate metal concentrations in these food items based on measured COPEC levels in sediment in the Animas River. The food intake equations and the estimated COPEC tissue levels are all based on dry weight. Note that the benthic invertebrate tissue levels used in the dose calculations are measured values from organisms collected from the Animas River in September 2014, except for sampling locations A73B and A75B from which benthic invertebrates were not collected.

4.6 Wildlife EDDs

The COPEC specific wildlife EDDs were calculated using the input parameters summarized in Section 4.5. **Tables 4.40 to 4.46** provide the EDDs for the American dipper, **Tables 4.47 to 4.53** and **Tables 4.54 to 4.60** provide the EDDs for the mallard 100% diet, and 50%-50% diet, respectively. **Tables 4.61 to 4.67** provide the EDDs for the belted kingfisher, and **Tables 4.68 to 4.74** to provide the EDDs for the muskrat.

5.0 RISK CHARACTERIZATION

5.1 Introduction

The potential for ecological risk is determined during risk characterization. The exposure analysis and effects analysis described in previous sections of this report are integrated to determine the likelihood of adverse effects to the assessment endpoints, given the assumptions inherent in the analysis phase.

Table 5.1 summarizes the risk estimation approaches for each of the receptor groups evaluated in this BERA. Risk was quantified mostly using the HQ method, which compares measured exposures (i.e., surface water, sediment, and pore water EPCs) or estimated exposures (wildlife EDDs) to corresponding toxicity values (i.e., chronic surface water benchmarks or no-effect and effect sediment benchmarks, plus wildlife no-effect and effect TRVs).

COPEC-specific HQs are then calculated using the following general equation:

$$HQ = EPC \text{ or } EDD/\text{benchmark or } TRV$$

Where:

HQ	=	Hazard Quotient (unitless)
EPC	=	Exposure Point Concentration (μg/L or mg/kg)
EDD	=	Estimated Daily Dose (mg/kg bw-day)
Benchmark	=	surface water or sediment benchmark (μg/L or mg/kg)
TRV	=	wildlife Toxicity Reference Value (mg/kg bw-day)

HQs at or above 1.0 identify a potential for ecological risk under the exposure and toxicity assumptions used in this evaluation. Note that the text below uses the terms minor/low risk (CTE effect HQs < 2.0), moderate risk (CTE effect HQs > 2 but < 5.0), or high risk (CTE effect HQs > 5.0), even though it is understood that risk does not increase in a linear fashion with increasing HQs. However, this terminology is used to qualitatively highlight differences in risk.

Besides assessing the potential impacts associated with RME and CTE surface water and sediment exposures, the risk characterization for community-level aquatic receptor groups also views each surface water and sediment sample as representing an individual event in which organisms are exposed to COPECs. Hence, HQs were calculated for all available surface water and sediment samples and were plotted by sampling station and period. Risk may be acceptable if the community as a whole remains healthy and stable over time. It is assumed that community-level risks are unlikely to occur if all the HQs measured within a particular EU fall below 1.0. On the other hand, community-level risks are more likely to occur if most or all of the individual

HQs exceed 1.0. Finally, some impact may occur, but without resulting in community-level effects, if only a small portion of the HQs exceeds 1.0.

Finally, the risk characterization does not quantify "incremental risk" by subtracting reference risk from Site risk.   Hence, the risks summarized in this section for each EU represent "total" risk.

Uncertainty is an inherent feature of this BERA because many assumptions were made in order to proceed with the evaluation. These assumptions affect all aspects of the assessment, including the CSM, the effects analysis, the exposure analysis, and the risk characterization. The uncertainty analysis identifies and discusses the major assumptions made in this BERA. The end result is a balanced overview of uncertainty to help risk managers understand the full extent of potential ecological risk to receptors living or feeding in mainstem Cement Creek, mainstem Mineral Creek, and the three Animas River reaches.

5.2 Community-level aquatic receptors - Benthic Invertebrates

Assessment endpoint 1: Maintain a stable and healthy benthic invertebrate community. *Are the metal levels in sediment from mainstem Cement Creek, mainstem Mineral Creek, and the Animas River above mainstem Cement Creek and below mainstem Mineral Creek high enough to impair the benthic invertebrates in these waterways?*

The potential for ecological risk to the benthic invertebrate community in the three waterways was assessed as follows.

5.2.1 Measurement endpoint 1A

Compare the metal levels measured in sediment samples to sediment benchmarks.

5.2.1.1 Mainstem Mineral Creek

Table 5.2 presents the no effect and effect HQs for benthic invertebrates exposed to COPECs in sediment from mainstem Mineral Creek.

All six sediment COPECs have no-effect HQs above 1.0. But only three of those six COPECs have an effect HQ above 1.0, with the highest HQs associated with Pb (RME effect HQ = 1.9 and CTE effect HQs = 1.4).

The data suggests that sediment in mainstem Mineral Creek close to the confluence with the Animas River present low levels of risk to the local benthic invertebrate community.

5.2.1.2 Mainstem Cement Creek

Table 5.3 presents the no-effect and effect HQs for benthic invertebrates exposed to COPECs in sediment from mainstem Cement Creek. The RME and CTE EPCs are identical to each other because only one sediment sample was collected from this EU.

All five sediment COPECs have no-effect HQs above 1.0. But only two of those five COPECs have effect HQs above 1.0, with the highest HQs associated with Pb (RME and CTE effect HQs = 2.2).

The data suggests that sediment in mainstem Mineral Creek close to the confluence with the Animas River presented moderate levels of risk to the local benthic invertebrate community.

5.2.1.3 Animas River

Animas River above mainstem Cement Creek

Table 5.4 presents the no-effect and effect HQs for benthic invertebrates exposed to COPECs in sediment from the Animas River above mainstem Cement Creek. Except for Hg and Se, all seven remaining COPECs have RME or CTE effect HQs above 1.0.

The three COPECs with the highest effect HQs consist of Pb (RME effect HQ = 13.5 and CTE effect HQ = 11.8), Mn (RME effect HQ = 10.5 and CTE effect HQ = 8.8) and Zn (RME effect HQ = 8.8 and CTE effect HQ = 6.9).

The data suggests that sediment in the Animas River above mainstem Cement Creek present high levels of risk to the local benthic invertebrate community.

- **Animas River at sampling location A72 below mainstem Mineral Creek**

Table 5.5 presents the no-effect and effect HQs for benthic invertebrates exposed to COPECs in sediments from sampling location A72. Al, Cd, Ni, Se, and Ag have RME and CTE effects HQs below 1.0 and are therefore of no further concern.

The three COPECs with the highest effect HQs consist of Pb (RME effect HQ = 4.5 and CTE effect HQ = 3.7), Mn (RME effect HQ = 2.5 and CTE effect HQ = 1.8) and Zn (RME effect HQ = 1.8 and CTE effect HQ = 1.4).

The data suggest that sediment at sampling location A72 presents moderate levels of risk to the local benthic invertebrate community.

- **Animas River at sampling location A73 below mainstem Mineral Creek**

Table 5.6 presents the no effect and effect HQs for benthic invertebrates exposed to COPECs in sediments from sampling location A73. Al, Ni, Se, and Ag have RME and CTE effects HQs below 1.0 and are therefore of no further concern.

The three COPECs with the highest effect HQs consist of Pb (RME effect HQ = 5.7 and CTE effect HQ = 4.0), Mn (RME effect HQ = 5.5 and CTE effect HQ = 3.6) and Zn (RME effect HQ = 3.0 and CTE effect HQ = 2.3).

The data suggests that sediment at sampling location A72 present moderate levels of risk to the local benthic invertebrate community.

- **Animas River at sampling location A73B below mainstem Mineral Creek**

Table 5.7 presents the no-effect and effect HQs for benthic invertebrates exposed to COPECs in sediments from sampling location A73B. Al, Cd, Ni, Se, and Ag have RME and CTE effects HQs below 1.0 and are therefore of no further concern.

The three COPECs with the highest effect HQs consist of Pb (RME effect HQ = 4.6 and CTE effect HQ = 4.2), Zn (RME effect HQ = 3.7 and CTE effect HQ = 2.4) and Mn (RME effect HQ = 3.6 and CTE effect HQ = 2.6).

The data suggest that sediment at sampling location A73B present moderate levels of risk to the local benthic invertebrate community.

- **Animas River at sampling location A75D below mainstem Mineral Creek**

Table 5.8 presents the no-effect and effect HQs for benthic invertebrates exposed to COPECs in sediments from sampling location A75D. Al, As, Ni, Se, and Ag have RME and CTE effect HQs below 1.0 and are therefore of no further concern.

The three COPECs with the highest effect HQs consist of Zn (RME effect HQ = 6.1 and CTE effect HQ = 3.8), Mn (RME effect HQ = 5.3 and CTE effect HQ = 3.6) and Pb (RME effect HQ = 2.9 and CTE effect HQ = 2.3).

The data suggests that sediment at sampling location A75D present moderate levels of risk to the local benthic invertebrate community.

- **Animas River at sampling location A75B below mainstem Mineral Creek**

Table 5.9 presents the no effect and effect HQs for benthic invertebrates exposed to COPECs in sediments from sampling location A75B. Al, Ni, Se, and Ag have RME and CTE effect HQs below 1.0 and are therefore of no further concern.

The three COPECs with the highest effect HQs consist of Zn (RME effect HQ = 11.6 and CTE effect HQ = 4.8), Pb (RME effect HQ = 3.4 and CTE effect HQ = 2.3) and Mn (RME effect HQ = 3.2 and CTE effect HQ = 2.3).

The data suggests that sediment at sampling location A75B present moderate levels of risk to the local benthic invertebrate community.

- **Animas River at sampling location Bakers Bridge below mainstem Mineral Creek**

Table 5.10 presents the no-effect and effect HQs for benthic invertebrates exposed to COPECs in sediments from sampling location BBridge. Al, As, Ni, Se, and Ag have RME and CTE effects HQs below 1.0 and are therefore of no further concern.

The three COPECs with the highest effect HQs consist of Zn (RME effect HQ = 18.6 and CTE effect HQ = 10.1), Mn (RME effect HQ = 10.9 and CTE effect HQ = 6.2) and Cd (RME effect HQ = 3.7 and CTE effect HQ = 2.0).

The data suggests that sediment at sampling location BBridge present high levels of risk to the local benthic invertebrate community.

Risk conclusion for measurement endpoint 1A

Mainstem Mineral Creek and mainstem Cement Creek have the lowest risk levels associated with metals in sediment. Pb, Mn, and Zn show a consistent potential for risk across all the Animas River EUs. The HQ data for the three risk drivers were used to calculate a geometric mean of the no effect RME and CTE HQs, and the effect RME and CTE HQs at each of the Animas River EUs. These averaged HQs were then plotted for visualization (see **Figure 5.1**). The reach above mainstem Cement Creek represents the highest levels of risk for benthic invertebrates exposed to sediment. Risk from Pb, Mn, and Zn is still present in the Animas River below mainstem Mineral Creek, but at a lower level.

The risk from Zn in sediment increases at sampling location A75B (situated just downstream of the confluence with Cascade Creek) and is higher still at the BBridge sampling location situated about eleven miles further downstream. This pattern suggests that, in response to the decrease in gradient of the River near BBridge, metals may have been deposited. Or an unknown source of metals could be present in this stretch of the Animas River.

Figure 5.2 shows the sample-specific no effect and effect sediment HQs for Al, As, Cd, Cu, Pb, Mn, Ag, and Zn at each EU. This approach assumes that each sediment sample represents an exposure point within a particular EU (instead of calculating EU-wide RME and CTE EPCs for deriving the HQs presented above). The same general pattern is apparent from these data, namely: (a) the sediment quality at the mouths of mainstem Cement and Mineral Creeks is no worse, and in many cases substantially better, than in the reaches of the Animas River above and

below these two creeks, (b) Pb, Mn and Zn are the major sediment risk drivers to the benthic invertebrate community in the Animas River, and (c) sediment risk is typically higher in the Animas River above mainstem Cement Creek compared to below mainstem Mineral Creek, indicating the presence of one or more contaminant sources further upstream.

5.2.2 Measurement endpoint 1B

Compare the metal levels measured in pore water samples collected from substrate in the field to chronic surface water benchmarks.

The pore water risk characterization consists of calculating RME and CTE HQs for all the pore water COPECs identified across the various EUs. A complicating factor in these risk calculations is that the toxicity of many COPECs depends on hardness. Hence, the pore water RME and CTE EPCs for the hardness-sensitive metals presented in Section 4 needed to be compared to chronic benchmarks adjusted for "reasonable minimum" and "average" pore water hardnesses (note: the toxicity of hardness-sensitive metals increases with decreasing hardness; hence, a reasonable minimum hardness was required as a conservative value for use in the pore water HQ calculations).

A reasonable minimum hardness was obtained as follows:

- The pore water hardness data were organized by EU (note: not enough pore water samples were available to calculate hardness by hydrologic period).
- For datasets too small to be evaluated using the ProUCL software, an average and a minimum pore water hardness was obtained from the available data to derive the pore water HQs for the hardness-sensitive metals.
- For the larger dataset (i.e., Animas River above mainstem Cement Creek), a 95% UCL and an average pore water hardness were calculated, after which the difference between the 95% UCL and the average was subtracted from the average to obtain a "reasonable minimum" pore water hardness value. Both the average and reasonable minimum hardness values were then used to calculate chronic benchmarks and derive the pore water HQs for the hardness-sensitive metals.

Table 5.11 summarizes the procedure used to obtain the hardness values required to calculate the pore water RME HQ and CTE HQs for the hardness-sensitive metals. Note that the RME and CTE HQs for Al were derived using only the standardized chronic benchmark of 87 µg/L, even though CDPHE (2013) determined that the toxicity of Al in surface water is sensitive to hardness. The reason for using this simplifying step is that CDPHE (2013) also requires evaluating pH as an additional variable to determine if the hardness-sensitive equation or the standard benchmark of 87 µg/L should be used. The pH of the pore water samples are not available.

5.2.2.1 Mainstem Mineral Creek

Table 5.12 presents the chronic HQs for benthic invertebrates exposed to COPECs in pore water from mainstem Mineral Creek.

Two COPECs are retained for further evaluation but neither one is present above its analytical DL in the one pore water sample collected from this EU. The RME and CTE HQs equal 1.5 for Be and 1.9 for Ag.

These results are inconclusive because they are derived from non-detect data. However, the lack of risk from the other COPECs suggests that pore water is unlikely to be a major risk factor in this EU. This conclusion is highly tentative because it is based on a single sample.

5.2.2.2 Animas River

Animas River above mainstem Cement Creek

Table 5.13 presents the chronic HQs for benthic invertebrates exposed to COPECs in pore water from the Animas River above mainstem Cement Creek. Eight of the nine COPECs have RME and CTE chronic HQs above 1.0. Cd, Cu and Zn are the three COPECs with the highest HQs.

The HQs for these three metals indicate the presence of high risk to benthic invertebrates exposed to pore water at this EU. However, a review of the analytical data (see **Appendices 3.1 and 3.2**) shows that this risk is driven by unusually high concentrations measured at sampling location A61 in April 2014 ([Cd] = 100 µg/L; [Cu] = 2,250 µg/L; [Zn] = 29,900 µg/L) and in September 2014 ([Cd] = 106.5 µg/L; [Cu] = 95.9 µg/L; [Zn] = 18,490 µg/L). Lower, but still substantial levels of these three metals were also measured at sampling location A65 during the same two 2014 pore water sampling events. It is unclear if these high levels represent potential hot spots. It is noteworthy that the metal levels in the pore water samples collected from sampling locations A60 (April and September 2014) and A64 (April 2014 only—a pore water sample was not collected from A64 in September 2014), appear more normal. A60 is located upstream of A61, whereas A64 is located between A61 and A65.

The data suggests that pore water, at least in some locations of the Animas River above mainstem Cement Creek, presents high risk to the local benthic invertebrate community, but that this risk may be localized.

- **Animas River at sampling location A72 below mainstem Mineral Creek**

Table 5.14 presents the chronic HQs for benthic invertebrates exposed to COPECs in pore water collected from sampling location A72. Al, Be, Cd, Ag, and Zn have RME and CTE chronic HQs above 1.0.

The three COPECs with the highest chronic HQs consist of Zn (low hardness RME chronic HQ = 8.8), Al (RME chronic HQ = 5.9), and Cd (low hardness RME chronic HQ = 5.0).

The data suggest that pore water at sampling location A72 presents a high risk to the local benthic invertebrate community.

- **Animas River at sampling location A73 below mainstem Mineral Creek**

Table 5.15 presents the chronic HQs for benthic invertebrates exposed to COPECs in pore water collected from sampling location A73. Be, Cd, Ag, and Zn have RME and CTE chronic HQs above 1.0.

The three COPECs with the highest chronic HQs consist of Zn (low hardness RME chronic HQ = 4.0), Cd (low hardness RME chronic HQ = 3.5), and Ag (low hardness RME chronic HQ = 1.6).

The data suggests that pore water at sampling location A72 presents moderate risk to the local benthic invertebrate community.

- **Animas River at sampling location A73B below mainstem Mineral Creek**

Table 5.16 presents the chronic HQs for benthic invertebrates exposed to COPECs in pore water collected from sampling location A73B. Be and Ag have RME and CTE chronic HQs above 1.0.

These two COPECs are retained for further evaluation but neither one is present above its analytical DL in the one pore water sample collected from this EU in September 2014. The RME and CTE chronic HQs equal 1.5 and 11 for Be and Ag, respectively.

These results are inconclusive because they are derived from non-detect data. However, the lack of risk from the other COPECs suggests that pore water is unlikely to be a major risk driver in this EU. This conclusion is highly tentative because it is based on a single sample.

- **Animas River at sampling location A75D below mainstem Mineral Creek**

Table 5.17 presents the chronic HQs for benthic invertebrates exposed to COPECs in pore water collected from sampling location A75D. Be, Cd, Ag, and Zn have RME and CTE chronic HQs above 1.0.

The three COPECs with the highest chronic HQs consist of Ag (low hardness RME chronic HQ = 3.6), Cd (low hardness RME chronic HQ = 1.9), and Zn (low hardness RME chronic HQ = 1.6).

Ag was not detected in either pore water samples collected in 2014. The Ag HQs are derived using one-half the highest DL and are therefore highly uncertain. The data suggest that pore water at sampling location A75D present low risk to the local benthic invertebrate community.

- **Animas River at sampling location Bakers Bridge below mainstem Mineral Creek**

Table 5.18 presents the chronic HQs for benthic invertebrates exposed to COPECs in pore water collected from sampling location BBridge. Be, Fe, Mn, and Ag have RME and CTE chronic HQs above 1.0.

The three COPECs with the highest chronic HQs consist of Mn (low hardness RME chronic HQ = 3.3), Ag (RME chronic HQ = 2.3), and Be (RME chronic HQ = 1.5).

Be and Ag were not detected in either pore water samples. Their HQs are derived using one-half the highest DL and are therefore highly uncertain. The data suggest that pore water at sampling location BBridge presents moderate risk to the local benthic invertebrate community.

Risk conclusion for measurement endpoint 1B

High pore water risk in bedded sediment was identified in the Animas River above mainstem Cement Creek. Much of that risk is associated with one sampling location (A61) that shows unusually high levels of contamination in the pore water samples collected in April and September 2014. The sample locations upstream (A61) and downstream (A64) from A61 appear much less impacted, suggesting that the high contaminant levels at A61 may represent a pore water "hot spot".

Low to moderate pore water risk is associated with most of the sampling locations in the Animas River below mainstem Cement Creek.

5.2.3 Measurement endpoint 1C

Assess survival and growth of H. azteca exposed for ten days to field-collected sediment samples.

Section 3.6.2 summarizes the results of the two sediment toxicity tests performed in December 2012 and November 2014. All the field-collected samples resulted in a statistically significant response, either in terms of increased mortality (particularly in the December 2012 test) or reduced biomass (in both toxicity tests). The most toxic samples are associated with CC49 (mainstem Cement Creek; 0% survival), M34 (mainstem Mineral Creek; 8.8% survival) and sampling location A73B (5.0 %) survival). Except for sampling location A56, survival in the other locations tested both in December 2012 and November 2014 is substantially higher (i.e., A68, A72, and BBridge), suggesting a temporal aspect to sediment quality or an improvement in sediment quality. However, biomass was still significantly affected in November 2014. The survival in sediment from "upstream" location A56 equaled 62.5% in December 2012 and 43.8%

in December 2014. This pattern indicates that sediment at this location is impacted by one or more sources further upgradient that are unrelated to inputs from mainstem Cement Creek or mainstem Mineral Creek.

Risk conclusion for measurement endpoint 1C

The two, ten-day *H. azteca* sediment toxicity tests identified severe effects, either on survival, growth, or both of these endpoints combined, in all of the sediment samples. The lowest survival was measured in the samples collected from M34, CC49, A72 and A73B. However, survival and biomass measured in all the other sampling locations were also significantly lower compared to the laboratory control sample. It is concluded that acute toxicity is present at all of the sediment sampling locations tested in December 2012 and November 2014 between A56 and BBridge.

5.2.4 Measurement endpoint 1D

Section 3.6.3 describes the results of the 2014 benthic community survey. In the fall of 2010, Mr. Chester Anderson (B.U.G.S. Consulting) prepared a benthic community data analysis report for the Animas River Stakeholder's Group (see **Appendix 16**). This report summarized the results of benthic surveys performed in the Animas River, Cement Creek, and Mineral Creek in 1992, 1996, 1997, 2004, 2006, 2007, 2009, and 2010. Mr. David Rees from Timberline Aquatics took these historic data and reworked them to generate standardized MMIs to allow for direct comparisons with the 2014 benthic survey. **Appendix 20** summarizes the outcome of this effort.

The MMI was calculated for stations along the Animas River from 1992 to 2014 in order to assess the benthic aquatic community over time. In order to derive standardized MMIs, all taxa were normalized across the years to make valid comparisons across the sampling locations. The pre-2014 data did not have specific taxa identified to the lowest level needed for the MMI. The data re-evaluation performed by Timberline Aquatics used the lowest-available taxonomic level from the historical data. The 2014 data were then adjusted to match these lower-resolution values. As a result, the MMI scores presented below may be biased low because some species groups (particularly chironomids) are not identified to the lowest-possible level. Also, the collection methods for the historical data varied across years (e.g., Surber, kicknet, or undocumented collection methods) which could also affect some of the MMI scores.

To simplify the graphs and the data interpretation, it was decided to (a) plot the MMI scores for the locations on the Animas River downstream of mainstem Mineral Creek (see **Figure 5.3a**) separate from locations A68 and M34 (see **Figure 5.3b**), (b) plot only those locations with data for at least four different sampling years (this restriction removed locations A53, A55, A56, A60, CC49, and BBridge), and (c) plot only those years when at least three locations were sampled (this restriction removed sampling years 1992 [n=2], 2003 [n=1], 2005 [n=1], and 2006 [n=1]). Note, however, that **Appendix 20** provides <u>all</u> the MMI scores.

The historic MMI scores can be interpreted as follows:

- The benthic invertebrate community has been unimpaired at Reference location A75CC, A75D (Animas River below mainstem Mineral Creek) and James Ranch (Animas River below BBridge) over the last 20 years. One exception occurred at the James Ranch location in 2003 when the MMI score showed short-term impairment (see **Appendix 20**; the 2003 sample year was excluded from **Figure 5.3a** for reason (c) in the previous paragraph)

- The benthic invertebrate community has been chronically impaired at A72, A73, and M34 over the last 20 years.

- The benthic invertebrate community has been intermittently impaired at A73EC (reference location) and A68.

Risk conclusion for measurement endpoint 1D

The MMI scores indicate that the conditions for the benthic invertebrate community at sampling locations A72 and A73 in the Animas River, and at sampling location M34 in mainstem Mineral Creek, have remained impaired since the mid-1990's. The occasional impairment at sampling location A68 points to a source of contamination further upstream in the watershed. The benthic invertebrate community at sampling locations A75D and James Ranch is unimpaired.

Risk conclusion for assessment endpoint 1 (benthic invertebrate community)

Taken together, the four independent measurement endpoints (i.e., comparison of bulk sediment chemistry to sediment benchmarks, comparison of field-collected pore water chemistry to surface water benchmarks, sediment toxicity tests, and recent plus past benthic community survey results) show a strong potential for risk to the benthic invertebrate community in various sections of the Animas River, as well as in mainstem Cement and Mineral creeks.

The sediment HQ evaluation and sediment toxicity test results do not provide a consistent picture. The sediment HQ analysis identifies sediment samples CC49 and M34 as the least impacted by metals, whereas sediment samples A75B, BBridge, and the Animas River upstream of Cement Creek are the most impacted by metals. This pattern is contrary to the outcome of the sediment toxicity test, which shows the highest toxicity at CC49 and M34 and lower (relative) toxicity in the Animas River above mainstem Cement Creek, plus A75B and BBridge.

Appendices 17.a and 17.b compare the *H. azteca* mortality and biomass responses from the two sediment toxicity tests (summarized in **Table 3.23**) against the HQs of key "risk-driving" metals measured in pore water and corresponding sediment samples collected from each of the toxicity test vessels in December 2012 and November 2014. The data analysis proceeded as follows:

- The evaluation focused on metals that yielded the highest HQs. Those metals are Al, As, Cd, Cu, Pb, Mn, and Zn.
- The sediment toxicity tests pore water HQs for the non-hardness dependent metals were obtained by dividing the detected concentrations (or half the DL for non-detect metals) of the dissolved metals measured in pore water by their corresponding chronic surface water benchmarks presented in **Table 3.1**
- The sediment toxicity tests pore water HQ for the hardness-dependent metals were obtained using the equations presented in **Table 3.1** to first calculate chronic surface water benchmarks based on the sample's hardness value and then dividing the dissolved concentrations of the hardness-dependent metals measured in pore water by these sample-specific surface water benchmarks (note: Al HQs were calculated using the standard benchmark of 87 μg/L).
- The sediment toxicity tests sediment HQs were calculated by dividing the detected concentrations (or half the DL for non-detect metals) by their corresponding effect sediment benchmarks presented in **Table 3.1**.

The results, which do not provide a consistent pattern, can be interpreted as follows:

December 2012 test (**Appendix 17.a**)

- The highest risk potential to *H. azteca* is associated with exposure to Pb, Mn and Zn in the bulk sediment, followed by As, Cd, and Cu.
- Toxicity to *H. azteca* from exposure to pore water in the test sediment appears to be sporadic across the sampling locations, except for Mn.
- Only for sampling location CC49 can it be stated with some level of confidence that pore water may have been a likely cause of the observed toxicity to *H. azteca*.
- The high toxicity at sampling location M34 is puzzling giving the relative absence of pore water or bulk sediment risk (e.g. compare the response and chemistry of M34 to A68). This observation suggests the presence of an unaccounted factor resulting in high toxicity to benthic invertebrates in mainstem Mineral Creek.

November 2014 test (**Appendix 17.b**)

- The highest risk potential to *H. azteca* is associated with exposure to Pb, Mn and Zn in the bulk sediment, followed by Cd and Cu.
- Toxicity from exposure to pore water in the test sediment is most pronounced for Cd, followed by Mn and Zn. However, the highest Cd risk associated with power water exposure occurs at the sample collected from location A60, even though *H. azteca* survival and biomass in that sample are no worse than at other locations.
- With some exceptions, the initial and final pore water HQs are remarkably similar. This pattern suggested that equilibrium between the pore water and bulk sediment was established within 24 hours of adding the sediment samples to the test beakers, and that

the daily surface water renewal in the test beakers over the ten-day test did not affect the composition of the pore water.

The chemistry versus toxicity evidence, although contradictory, was weighed in favor of the sediment toxicity test because it measured direct effects on a sensitive benthic invertebrate species exposed for ten days to field-collected sediment samples. Additionally, the two sediment toxicity tests met the test acceptability criteria for both survival and growth, and are therefore valid for use in this report. The exact cause of toxicity to *H. azteca* (and by extension the benthic invertebrate community) is unclear, but the effects on survival and growth are uncontroversial.

5.3 Community-level aquatic receptors – fish

The risk characterization for fish based on analytical chemistry uses two separate but complimentary approaches.

The first approach is identical to the one described in Section 5.2.2 to derive "reasonable minimums" and average hardness values for use in calculating hardness-specific chronic surface water benchmarks for deriving HQs. **Table 5.19** presents the surface water hardness values for each EU and hydrologic period.

The second approach consists of assessing key surface water COPECs (i.e., pH, Al, Cd, Cu, Mn, Pb, and Zn) on a sample-by-sample basis by creating HQ scatter plots. These plots are provided in **Figure 5.4.a-c** (pH), **Figure 5.5.a-c** (total Al), **Figure 5.6.a-c** (dissolved Cd), **Figure 5.7.a-c** (dissolved Cu), **Figure 5.8.a-c** (dissolved Mn), **Figure 5.9.a-c** (dissolved Pb), and **Figure 5.10.a-c** (dissolved Zn). The equations developed by CDPHE (2013) for calculating the hardness-dependent metal benchmarks used in deriving the HQs plotted in these figures are designed to be protective of most aquatic species in CO waters. Hence, the HQs derived from these hardness-adjusted benchmarks tend to be conservative.

An additional set of scatter plots was created specifically for Cd (**Figure 5.6*.a-c**), Cu (**Figure 5.7*.a-c**) and Zn (**Figure 5.10*.a-c**) to assess the potential effects of these three metals on four individual trout species, namely brook trout, brown trout, rainbow trout, and cutthroat trout. *These scatter plots are structurally different from the others* because they do not provide HQs but instead show dissolved metals <u>concentrations</u> (see **Appendix 7.1*, 7.2*, and 7.3***) standardized to a hardness of 50 mg/L using the approach presented in **Appendix 5.a**. The purpose for standardizing all of the Cd, Cu, and Zn surface water concentrations to a common hardness of 50 mg/L is to allow for a direct comparison to the chronic toxicity thresholds developed for brook trout, brown trout, rainbow trout, and cutthroat trout as presented in Table 1 of **Appendix 5**. These thresholds are shown by the horizontal lines in the Cd, Cu and Zn scatter plots provided in **Figures 5.6*, 5.7*, and 5.10***, respectively.

Assessment endpoint 2: Maintain a stable and healthy fish community. *Are the metal levels in surface water from mainstem Cement Creek, mainstem Mineral Creek, and the Animas River*

above mainstem Cement Creek, between mainstem Cement Creek and mainstem Mineral Creek, and below mainstem Mineral Creek high enough to impair the fish in these waterways?

The potential for ecological risk to the fish community is assessed as follows.

5.3.1 Measurement endpoint 2A

Compare metal levels measured in surface water samples to chronic surface water benchmarks.

5.3.1.1 Mainstem Mineral Creek

Table 5.20 presents the surface water HQs for the fish community in mainstem Mineral Creek. All surface water samples were collected at one location (M34) by the mouth of the creek.

- **pH**

Figure 5.4.a provides the scatter plots for pH in this EU. The data show that surface water pH can drop as low as around 5.0 during the pre-runoff period, but then stays mostly at or above 6.0 during the runoff and post-runoff period.

- **Metals**

The RME and CTE HQs for Al, Cd, Fe, Ag, and Zn have HQs above 1.0 during all three hydrologic periods. The highest risk in this EU is associated with severe Al exceedances. The other exceedances are relatively minor in comparison. The risk from Ag is highly uncertain because it is based mostly on half of the analytical DLs, as opposed to actual detected concentrations.

The HQ scatterplots for mainstem Mineral Creek show the same general pattern, with the highest risk associated with total Al during all three hydrologic periods.

The concentration scatter plots do not show any risk to brown trout or rainbow trout from Cd or Cu (see **Figures 5.6*.a and 5.7*.a**) and minimal risk to both of these trout species from chronic exposure to Zn during the pre-runoff period (see **Figure 5.10*.a**).

It is concluded that surface water pHs of around 5.0 combined with high Al levels during the pre-runoff period can be potentially lethal to aquatic receptors depending on the duration of the low pH or high Al event. At a minimum, such conditions are expected to cause severe stress to fish during the pre-runoff period.

5.3.1.2 Mainstem Cement Creek

Table 5.21 presents the surface water HQs for aquatic, community-level receptors in mainstem Cement Creek. All surface water samples (except for one obtained at CC49) were collected from CC48, located close to the confluence with the Animas River.

- **pH**

Figure 5.4.a provides the scatter plots for pH in this EU. The data show that pH remained entirely below 6.0 during all sampling events between 2009 and 2014, with pH excursions well below 4.0 during both the pre and post-runoff seasons. Irrespective of the surface water metals concentrations presented below, these pH levels will be acutely lethal to all fish.

- **Metals**

The RME and CTE HQs for Al, Be, Cd, Cu, Fe, Mn, Pb, and Zn exceed 1.0 during all three hydrologic periods. The highest risk in this EU is associated with severe Al exceedances. The other exceedances are relatively minor in comparison, but are still expected to be lethal, particularly for Cd, Cu, and Zn.

The HQ scatterplots for mainstem Mineral Creek show the same general pattern. Total Al shows the highest risk during all three hydrologic periods, with Cd, Cu and Zn also contributing to risk.

The concentration scatter plots show minor risk associated with dissolved Cd to brown trout and rainbow trout (see **Figure 5.6*.a**). The risk to both species increases from exposure to dissolved Cu (see **Figure 5.7*.a**). Dissolved Zn also represents a risk to cutthroat trout, rainbow trout, and brown trout, but not to brook trout (see **Figure 5.10*.a**).

It is concluded that the chemical conditions in the surface water from mainstem Cement Creek cannot support a viable fish community.

5.3.1.3 Animas River

Animas River above mainstem Cement Creek.

Table 5.22 presents the surface water HQs for the fish community in the Animas River above mainstem Cement Creek.

- **pH**

Figure 5.4.a provides the scatter plots for pH in this EU. The data show that pH remained above 6.0 during all sampling events between 2009 and 2014. Hence, pH is not considered a stressor in this reach of the Animas River.

- **Metals**

Al, Cd, Cu, Mn, and Zn have HQs above 1.0 during one or more of the hydrologic periods, although the exceedances are in general relatively minor.

Figures 5.5.a (Al), **5.6.a** (Cd), and **5.10.a** (Zn) suggest the presence of a source of these metals upstream of this EU. The lack of a robust surface water dataset from sampling location A56 ("upstream") precludes determining if the Mayflower Mill, situated just above the confluence of Arrastra Creek with the Animas River between sampling locations A56 and A64, may be a potential source for these three metals, or if the source is located further upstream in the watershed.

The concentration scatter plots show minor risk associated with dissolved Cd to brown trout and rainbow trout during the pre-runoff period (see **Figure 5.6*.a**). The risk to both species is minimal from exposure to dissolved Cu (see **Figure 5.7*.a**). Dissolved Zn also represents a risk to cutthroat trout, rainbow trout, and brown trout, but not to brook trout (see **Figure 5.10*.a**).

It is conclude that the chemical conditions in the surface water from the Animas River upstream of mainstem Cement Creek between sampling locations A60 and A68 likely results in toxicity to the fish community, mainly due to Al, Cd, and Zn. Additionally, this potential risk is unrelated to contamination from mainstem Cement Creek which joins the river further downstream of this EU.

Animas River between mainstem Cement Creek and mainstem Mineral Creek

Table 5.23 presents the surface water HQs for the fish community in this short reach of the Animas River. Only two surface water samples were collected from the two sampling locations in October of 2012 (post-runoff period).

- **pH**

Figure 5.4.b provides the scatter plots for pH in this EU. The two data points show that the pH during the post-runoff period is at or below the minimum threshold of 6.0. Hence, pH could be a potential minor stressor in this reach of the Animas River. This acidity reflects input of low-pH surface water from mainstem Cement Creek located at the upstream end of the reach (see **Figure 1.1**). This conclusion is supported by the fact that pH in the Animas River above mainstem Cement Creek is invariably well above 6.0.

- **Metals**

Al, Cd, Cu, Fe, Mn, and Zn have HQs above 1.0 during the post-runoff period, although the exceedances are in general relatively minor, except for Al (**Table 5.23**).

The HQ scatterplots for the Animas River between mainsten Cement Creek and mainstem Mineral Creek show the same general pattern. Total Al shows the highest risk during the post-runoff period (the only period with data), with Cd, Cu and Zn also contributing to risk.

The concentration scatter plots show no risk associated with dissolved Cd or Cu to brown trout and rainbow trout (see **Figures 5.6*.a and 5.7*.a**). Dissolved Zn represents a risk to cutthroat and rainbow trout, but not to brown trout or brook trout (see **Figure 5.10*.a**).

The limited contaminant profile suggests that the surface water chemistry in this reach of the Animas River could cause severe chronic toxicity to fish from a combination of low pH and high Al levels, together with the presence of several other metals.

Animas River below mainstem Mineral Creek

Tables 5.24 to 5.30 present the surface water HQs for aquatic, community-level receptors in the seven EUs of the Animas River below mainstem Mineral Creek. Those EUs were combined for the purpose of this discussion because their risk patterns were quite similar.

- **pH**

Figures 5.4.b and c provide the scatter plots for pH in this reach of the Animas River. Sampling location A72 shows that pH drops to around 5.0 during the pre-runoff period. Surface water samples were collected from sampling locations A73, A75D, and BBridge in April 2014, but pH was not measured in any of these samples. None of the other EUs in this reach were sampled for surface water during the pre-runoff season. Hence, it is unknown how much further downstream the low pH extends prior to snowmelt. This acid pulse most likely originates from both mainstem Cement Creek and mainstem Mineral Creek (see **Figure 5.4.a**), instead of from further upstream on the Animas River. The sparse dataset for the EUs downstream from A72 suggests that pH is not an issue during the runoff and post-runoff periods.

- **Metals**

Al, Cd, Cu, Fe, Mn, and Zn have HQs above 1.0 during one or more of the hydrologic periods, although the exceedances are in general relatively small, except for Al which represents a substantial risk (**Tables 5.24 to 5.30**).

The HQ scatterplots for the Animas River below mainstem Mineral Creek show the same general pattern. Total Al shows the highest risk during all three hydrologic periods, with Cd, Cu and Zn also contributing to risk. Risk is also invariably the highest at sampling location A72.

The concentration scatter plots show no (or minimal) risk associated with dissolved Cd or Cu to brown trout and rainbow trout (see **Figures 5.6*.a and 5.7*.a**). Dissolved Zn represents some risk to cutthroat and rainbow trout, but not to brown trout or brook trout (see **Figure 5.10*.a**).

The limited contaminant profile suggests that the surface water chemistry in this reach of the Animas River could cause severe chronic toxicity to fish during the pre-runoff period from a combination of low pH and high Al levels. The presence of several other metals at lower concentrations might further exacerbate this trend.

Risk conclusion for measurement endpoint 2.A

The prevailing conditions in mainstem Cement Creek are expected to be acutely lethal to fish, mainly due to low pH and high Al levels, coupled with excessive amounts of Cd, Pb, and Zn.

The prevailing conditions in mainstem Mineral Creek appear to be less extreme but will still result in severe stress to fish, mainly due to low pH in the pre-runoff period and high Al levels throughout the year.

The prevailing conditions in the Animas River above mainstem Cement Creek reflect one or more sources of Al, Cd and Zn upstream of this reach, although low pH is not an issue. It appears likely that the prevailing conditions will result in stress to the local fish community in this reach of the river and potential lethality on a seasonal basis.

The prevailing conditions in the Animas River between mainstem Cement Creek and mainstem Mineral Creek can only be assessed based on two surface water samples. This limited dataset suggests that the conditions in this reach of the Animas River reflect input from mainstem Cement Creek and from the Animas River upstream of Cement Creek. Low pH and high Al are expected to be risk drivers to the local fish community, as well as Cd and Zn.

The prevailing conditions in the Animas River below Mineral Creek are difficult to assess properly because only sampling location A72, situated about one mile downstream of the confluence with mainstem Mineral Creek was sampled over a five-year period. The limited data suggest that Al, Cd, and Zn would likely result in chronic stress to the local fish community, even though a possible trend showed lower HQs further downstream. However, this trend could not be confirmed due to the few available data points.

To provide a partial remedy for this data gap, EPA installed “MiniSipper” sampling devices at several locations in the Animas River below mainstem Mineral Creek, specifically A73, A75D, and BBridge (note: MiniSippers were also installed at locations A56 and A68 in the Animas River above mainstem Cement Creek; however, the devices at locations A72 and A68 were lost during the 2014 spring runoff event). These sampling devices were deployed in mid-April before the spring runoff and retrieved in mid-July after the runoff concluded. On a daily basis, each device collected and stored a five milliliter integrated surface water sample within a sample coil. Each sample was preserved with 0.25 milliliter nitric acid (stabilizing reagent) to a pH of less than or equal to two and filtered in-situ through a ten micron, ultra-high molecular-weight polyethylene solvent filter. The filtered samples were separated from one another inside the

sample coil by a small injected nitrogen gas bubble. The sample coils were returned to the laboratory at the end of the three-month sampling period for analysis of the water samples for dissolved metals and hardness.

The interpretation of the MiniSipper analytical data focuses on Al, Cd, Cu, Pb, and Zn, all of which have aquatic toxicities that depend on hardness (CDPHE, 2013). For the latter four metals, the daily hardness concentrations were used to derive daily hardness-adjusted benchmarks. The metal concentrations measured that day were divided by their hardness-adjusted benchmarks to generate daily HQs. This approach was also used for Al, except that the Al data set did not include total Al concentrations and pH, both of which are required to derive Al benchmarks per the CDPHE (2013) guidance. Instead, the Al HQs were calculated by dividing the daily dissolved Al concentration by the standard benchmark of 87 µg/L provided by CDPHE (2013). All the available daily HQs were then plotted for the five metals over time and across the four sampling locations (i.e., A56, A73, A75D, and BBridge) to help visualize changes in risk to fish at select locations in the Animas River from mid-April 2014 until mid-July 2014.

Note that the MiniSipper data have important limitations, including the potential for "smearing" between adjacent samples in the sample coils, limited QA capabilities, and the need for using a 10 µm versus a 0.4 µm filter to generate the dissolved samples. As a result, the data are only used semi-quantitatively to provide the supporting evidence presented below.

Figure 5.11 summarizes the plots associated with this analysis, which can be interpreted as follows:

- Aluminum:

The Al HQs started increasing towards the middle of May 2014 and exceeded unity (HQ of 1.0) at the end of that month, except for sampling location A73. These HQ exceedances remained below 5.0 and were largely gone by the second half of June 2014. Sampling location A56 showed the highest risk from Al.

- Cadmium

The Cd HQs consistently exceeded 1.0 but stayed largely below 5.0 during the 2014 pre-runoff period at sampling locations A56, A73, and A75D. These HQ exceedances persisted throughout the runoff period, during which time the Cd HQs at BBridge were also slightly above 1.0. The excess risk from Cd was largely removed by mid-June 2014.

- Copper

Copper was not a risk issue at any of the three MiniSipper sampling locations on the Animas River below mainstem Mineral Creek between April and July 2014. The HQs exceeded 1.0 but stayed below 5.0 at sampling location A56 during the 2014 runoff period.

o Lead

The Pb HQs started increasing towards the middle of May 2014 and were above 1.0 at the end of that month, except for sampling location A73. These HQ exceedances stayed below 5.0, except for sampling location A56, and were largely gone by the second half of June 2014. Sampling location A56 showed the highest risk from Pb.

o Zinc

The pattern for the Zn HQs was similar to that observed for Cd, namely the HQs consistently exceeded 1.0 but stayed largely below 5.0 during the 2014 pre-runoff period at sampling locations A56, A73, and A75D. These HQ exceedances persisted throughout the runoff period, during which time the Zn HQs at BBridge were also slightly above 1.0. The excess risk from Zn was largely gone by mid-June 2014.

The 2014 MiniSipper data mostly reflect the general trends summarized in **Figures 5.5 to 5.10**, namely: (a) the risk to fish increases during the runoff period and then subsides later on in the summer, (b) risk from Cd and Zn is consistently present during the pre-runoff period (except for the BBridge sampling location), and (c) a persistent risk signal is associated with the samples collected at sampling location A56, located upstream of A60 on the Animas River above mainstem Cement Creek. Multi-week exceedances of chronic HQs at the various sampling locations on the Animas River can be expected to have long-term detrimental effects on the local fish populations.

As a final note, the Al HQs summarized in Figure **5.11a** are lower than those provided in **Figure 5.5** for the same sampling locations. The reason is partly because the benchmark calculation methods differed since the MiniSipper Al data represent dissolved Al and lack the pH data needed to select the proper HQ calculation method. Also, the cause behind the apparent Cu, Pb, and Zn spike at sampling location A56 on May 16, 2014 is not known. A large rain event occurred in the general area during this time frame but would not explain the immediate rise and fall observed in the data. The spike may also reflect an unknown sampling artifact associated with the MiniSipper apparatus on that day. Either way, Cd and Al did not spike at the same time, as might have been expected. Regardless, the general trends outlined above are not negated by the presence of this unexplained spike.

5.3.2 Measurement endpoint 2B

Assess survival in juvenile rainbow trout (Oncorhynchus mykiss) exposed for 96 hours in the laboratory to surface water samples collected from mainstem Cement Creek, mainstem Mineral Creek, and the Animas River above mainstem Cement Creek and below mainstem Mineral Creek.

Section 3.6.1 summarizes the results of the acute toxicity tests using juvenile rainbow trout. **Table 3.22** provided the survival data. The toxicity tests were performed using surface water collected during the pre-runoff period (April 2013) and the post-runoff period (October and November, 2012). No surface water samples were collected during the runoff period for use in toxicity testing.

Surface water samples collected from mainstem Cement Creek, mainstem Mineral Creek, and sampling location A72 on the Animas River below mainstem Mineral Creek were acutely toxic to juvenile rainbow trout. Sampling location A68 in the Animas River above mainstem Cement Creek was acutely toxic in April 2013 but not in the fall of 2012, strongly suggesting the presence of a seasonal chemical stressor in this reach of the river that is not associated with input from mainstem Cement or Mineral Creeks.

No significant acute toxicity was observed for juvenile rainbow trout exposed to surface water collected from the EUs below sampling location A72. This pattern suggests that the acute toxicity measured in A72 was "diluted out" by the time the river reached sampling location A73, about six miles downstream of the confluence with mainstem Mineral Creek.

5.3.3 Risk Conclusions for assessment endpoint 2 (fish community)

- **Mainstem Cement Creek:**

The chemical conditions in surface water from mainstem Cement Creek are highly toxic to fish, particularly due to low pH and high Al, and to a lesser extent by the presence of Cd, Cu, and Zn. The toxicity tests show that surface water collected from this EU in November (i.e., post-runoff period) was acutely toxic to juvenile rainbow trout (see **Table 3.22**). The preponderance of the evidence suggests that the fish community in mainstem Cement Creek (if present) would experience high stress under current conditions.

- **Mainstem Mineral Creek:**

The chemical conditions in mainstem Mineral Creek appear less severe than in mainstem Cement Creek for the local fish community. However, severe pH drops and high Al levels during the pre-runoff period suggest that fish may experience high stress in the winter, but that survivors could possibly recover during the remainder of the year. The toxicity tests showed that surface water collected from this EU in November (i.e., post-runoff period) was acutely toxic to juvenile rainbow trout (see **Table 3.22**). The preponderance of evidence suggests that the fish community in mainstem Mineral Creek (if present) would likely experience severe acute stress under current conditions.

- **Animas River above mainstem Cement Creek:**

The chemical conditions in the Animas River above mainstem Cement Creek suggest the presence of one or more sources of metal contamination located further upstream in the watershed. The chemical signature of the surface water suggests that chronic toxicity to the fish community is likely, particularly due to the presence of Al, Cd, and Zn. Low pH, on the other hand, is not an issue in this reach. The presence of significant acute toxicity measured in juvenile rainbow trout exposed to surface water from this reach further confirms the results of the chemical analyses. The preponderance of evidence suggests that the fish community in this reach of the Animas River may experience toxic stress during much of the year.

- **Animas River between mainstem Cement Creek and mainstem Mineral Creek**

The amount of chemical information on the quality of the surface water is limited because only two samples were collected and no acute toxicity testing was performed. The limited amount of data suggests that this reach of the Animas River is likely to be lethal to fish, mostly due to low pH and high levels of aluminum, with secondary stress caused by Cd and Zn.

- **Animas River below mainstem Mineral Creek**

The chemical signature of the surface water in this reach of the Animas River reflects the major inputs from mainstem Mineral and Cement Creek, and the reach of the Animas River above mainstem Cement Creek. Surface water samples collected from sampling location A72 during the pre and post-runoff periods were acutely toxic to juvenile rainbow trout. The surface water samples collected during the same two hydrologic periods from the EUs further downstream did not show acute toxicity, suggesting that the acute effects had been "diluted out". However, the preponderance of evidence (including the semi-quantitative MiniSipper datasets summarized in **Figure 5.11**) shows that Al, Cd, and Zn in surface water may exert chronic stress to the fish community all the way to the BBridge EU located about 30 miles downstream from Silverton.

This general conclusion is strongly supported by the results of periodic fisheries surveys performed by the Colorado Division of Wildlife (CDOW, 2010; see **Appendix 18**). The CDOW electroshocked the Animas River below mainstem Mineral Creek at locations "A-72 USGS" (equivalent to sampling location A72), "Elk Park" (in the vicinity of sampling location A73), and "Teft Spur" (in the vicinity of sampling locations A75D/A75B). The CDOW also sampled the Animas River above mainstem Cement Creek at Howardsville, situated about 4 miles northeast of Silverton. This sampling location, which falls well outside of the BERA EUs, is nonetheless included in this discussion for comparison purposes.

The data consist of fish counts ("fish per mile" organized by trout species) sampled at these four locations in 1992, 1998, 2005, and 2010 (see Table 5 on p. 15 in **Appendix 18**). CDOW returned to Teft Spur on the Animas River in September of 2014 for an additional electroshocking survey (see p. 29 to 32 in **Appendix 19**). The trout density data collected between 1992 and 2014 are summarized for brook trout (**Fig. 5.12.a**), rainbow trout (**Fig. 5.12.b**), and brown trout (**Fig. 5.12.c**). This information is discussed below. Note that the data for cutthroat trout are not plotted

because only four specimens were collected at Howardsville in 1992. This trout species has not been observed at any of the four sampling locations since then.

Brook trout (Fig. 5.12.a):

Brook trout are by far the most common of the four trout species collected from the Upper Animas River. The brook trout population in Howardsville was low in 1992 but expanded in subsequent years. As of 2010 (no samples were collected in 2014), the Animas River in Howardsville supports over 1000 brook trout per river mile.

Brook trout have essentially been absent at A72 since 1992. A small but stable brook trout population existed at A73 (Elk Park) between 1992 and 2005, but was eliminated by 2010. No sampling occurred at A73 in 2014 to determine if this situation has changed.

A more robust brook trout population was found at Tefts Spur between 1992 and 2005. By 2010, however, that population had been reduced by around 75%, followed by an additional 30% reduction in 2014.

Rainbow trout (Fig. 5.12.b):

A small rainbow trout population was present in the Animas River at Howardsville in 1992, but has been absent since 1998. No rainbow trout were captured at A72 between 1992 and 2010, or at A73 (Elk Park), except for a handful of fish in 2005. A small rainbow trout population was present at Tefts Spur in 1992, but declined until it had disappeared by 2010. No rainbows have been caught at this location since then.

Brown trout (Fig. 5.12.c):

No brown trout have been collected from the Animas River at Howardsville, A72, or A73 (Elk Park) since 1992. A few brown trout had established themselves at Teft Spur by 1998, expanded their population by 2005, but then disappeared by 2010. A small brown trout population was once again present at Teft Spur in 2014.

In conclusion, the available fisheries data shows that the current conditions in the Animas River downstream from the confluence with mainstem Cement and Mineral Creeks have had harmful effects on all trout species, including the more tolerant brook trout. The elimination of brook trout at A73 (Elk Park) between 2005 and 2010, and the strong decline of the brook trout population at Teft Spur between 2005 and 2014 is particularly striking. **Appendix 18** (p. 16) states that the decline in fish abundance suggests a substantial decline in surface water quality since 2005, which may have been associated with the closure of a water treatment project in 2004 on Cement Creek in the Gladstone area.

5.4 Aquatic invertivorous birds

The risk evaluation for the wildlife receptors generated numerous HQ tables. No effect and effect HQs were developed for both RME and CTE exposure scenario, resulting in four HQs for ten analytes across seven EUs on the Animas River. Four of the ten "important bioaccumulative compounds" assessed for risk via food chain modeling showed a potential for wildlife risk. Those compounds consisted of Cu, Pb, Se, and Zn.

The data presentation and interpretation outlined below for aquatic invertivorous birds (and the three other wildlife receptor species) was simplified by focusing the discussion only on those four compounds and calculating a geometric mean of the no effect and effect HQs for both the RME and CTE exposure scenario. A geometric mean was obtained by (a) taking the natural log of a no effect HQ and its corresponding effect HQ, (b) adding the two logged values, (c) dividing the sum by 2, and (d) taking the anti-log of the result. Those RME and CTE "geomean HQs" were then plotted for each wildlife receptor to help visualize the potential for ecological risk across all the Animas River EUs.

Assessment endpoint 3: Maintain stable and healthy invertivorous bird populations. *Are the metal levels in surface water, sediment, and benthic invertebrates high enough to impair invertivorous birds foraging in the Animas River above mainstem Cement Creek and below mainstem Mineral Creek?*

The potential for ecological risk to this receptor group is assessed using one measurement endpoint, as follows:

5.4.1 Measurement endpoint 3A

Use metal concentrations measured in sediment and benthic invertebrates in a food chain model to calculate metal-specific EDDs from ingesting surface water, sediment, and benthic invertebrates, and compare these EDDs to avian TRVs.

Tables 5.31 to 5.37 provide the HQs for this receptor across all of the wildlife EUs. **Figure 5.13.a** summarizes the geometric mean RME and CTE HQs for Cu, Pb, Se, and Zn. The potential risks associated with the four major COPECs are discussed below. The reliability of the findings is considered low because it is based on a single, semi-qualitative Line of Evidence (LOE).

This measure of effect identifies Cu as a risk driver to invertivorous birds ingesting surface water, sediment, and aquatic invertebrates from the Animas River at sampling locations A73B and A75B. The highest risk for Cu (RME geometric mean HQ = 5.6 and CTE geometric mean HQ = 2.6) is identified at A75B. Minor risk is also found for Zn (RME geometric mean HQ = 1.6 and CTE geometric mean HQ = 1.1) in the Animas River above mainstem Cement Creek, and for Se at sampling location A73B (RME geometric mean HQ = 1.2 and CTE geometric mean HQ = 1.2).

The southwestern willow flycatcher, which is listed as an endangered bird species both at the federal and state level, might forage for aquatic insects and breed in the riparian habitats along the Animas River downstream of Silverton. It is not known if this bird is actually present on the Animas River, but this BERA assumes it to be the case as a precautionary measure. It was decided that the no effect HQ under a RME scenario would provide a conservative assessment of risk for this protected species. Under that scenario, a potential for risk, primarily from Cu, but also from Se and Zn is identified both in the Animas River reach above mainstem Cement Creek and at sampling locations A73B and A75B in the Animas River below mainstem Cement Creek.

No benthic invertebrates were collected for tissue residue analysis from sampling locations A73B and A75B. Hence, the levels of metals in benthic tissues used in calculating EDDs were estimated using conservative published sediment-to-benthic invertebrate regression models and uptake factors. It is noteworthy that the only two sampling locations with excessive risk from Cu are A73B and A75B (see **Figure 5.13a**). Given this pattern, it is concluded that the risk from Cu is hypothetical and unlikely to be realized in the field.

5.5 Aquatic omnivorous birds

Assessment endpoint 4: Maintain stable and healthy omnivorous bird populations. *Are the metal levels in surface water, sediment, benthic invertebrates, and aquatic plants high enough to impair omnivorous birds foraging in the Animas River above mainstem Cement Creek and below mainstem Mineral Creek?*

The potential for ecological risk to this receptor group was assessed using one measurement endpoint, as follows:

5.5.1 Measurement endpoint 4A

Use metal concentrations measured in sediment samples to estimate metal residues in aquatic plants; use the estimated plant residues and the measured benthic invertebrate residues in a food chain model to calculate metal-specific EDDs from ingesting surface water, sediment, and food, and compare these EDDs to avian TRVs.

The risk to aquatic omnivorous birds, represented by the mallard, is assessed based on the “100% diet” to model females feeding exclusively on benthic invertebrates prior to laying their eggs in the spring, and on the “50%-50% diet” to model both males and females feeding on a mix of plants and benthic invertebrates for the remainder of the year.

Tables 5.38 to 5.44 provide the HQs for the 100% diet, and **Tables 5.45 to 5.51** provide the HQs for the 50%-50% diet. **Figures 5.13.d and 5.13.e** summarize the geometric mean RME and CTE HQs for Cu, Pb, Se, and Zn in the 100% diet and the 50%-50% diet, respectively. The potential risks associated with the four major COPECs are discussed below. The reliability of the findings is considered low because it is based on a single, semi-qualitative LOE.

- 100% benthic invertebrate diet

Of the four major COPECs, only Cu is a minor risk concern to the mallard feeding on a 100% benthic invertebrate diet at sampling locations A73B and A75B in the Animas River below mainstem Mineral Creek. Pb, Se, and Zn are not a risk concern under this exposure scenario. As explained in the previous subsection, the small risk associated with Cu is considered hypothetical because it is derived using estimated (instead of measured) benthic invertebrate tissue levels.

- 50% benthic invertebrate and 50% aquatic plant diet

None of the four major COPECs are a risk concern to the mallard feeding on a 50%-50% diet in the Animas above mainstem Cement Creek or below Mineral Creek. This finding suggests that mallards feeding on a 50%-50% diet are unlikely to be affected by the current conditions in the Animas River at the EUs evaluated in this BERA.

5.6 Piscivorous birds

Assessment endpoint 5: Maintain stable and healthy piscivorous bird populations. *Are the metal levels in surface water, sediment and fish high enough to impair piscivorous birds foraging in the Animas River above mainstem Cement Creek and below mainstem Mineral Creek?*

The potential for ecological risk to this receptor group was assessed using one measurement endpoint, as follows:

5.6.1 Measurement endpoint 5A

Use metal concentrations measured in sediment samples to estimate metal residues in fish; use food chain modeling to calculate metal-specific EDDs from ingesting surface water, sediment and fish, and compare these EDDs to avian TRVs.

Tables 5.52 to 5.58 provide the HQs for this receptor. **Figure 5.13b** summarizes the geometric mean RME and CTE HQs for Cu, Pb, Se, and Zn. The potential risks associated with the four major COPECs are discussed below. The reliability of the findings is considered low because it is based on a single, semi-qualitative LOE.

This measure of effect identifies Pb as a minor risk driver to piscivorous birds ingesting surface water and fish from the Animas River. Risk from Pb exceed unity (RME geometric mean HQ = 1.2 and CTE geometric mean HQ = 1.1) only in the reach of the Animas River above mainstem Cement Creek. Risk from Zn in the Animas River at the BBridge EU further downstream equals unity but only for the RME geometric mean HQs; the CTE geometric mean HQs for Zn all fall below one.

5.7 Aquatic herbivorous mammals

Assessment endpoint 6: Maintain stable and healthy herbivorous mammal populations. *Are the metal levels in surface water, sediment, and aquatic plants high enough to impair herbivorous mammals foraging in the Animas River above mainstem Cement Creek and below mainstem Mineral Creek?*

The potential for ecological risk to this receptor group was assessed using one measurement endpoint, as follows:

5.7.1 Measurement endpoint 6A

Use metal concentrations measured in sediment samples to estimate metal residues in aquatic plants; use food chain modeling to calculate metal-specific EDDs from ingesting surface water, sediment, and aquatic plants, and compare these EDDs to mammalian TRVs.

Tables 5.59 to 5.65 provide the HQs for this receptor. **Figure 5.13.c** summarizes the geometric mean RME and CTE HQs for Cu, Pb, Se, and Zn. The potential risks associated with the four major COPECs are discussed below. The reliability of the findings is considered low because it is based on a single, semi-qualitative LOE.

None of the four major COPECs are a risk concern to the muskrat consuming a 100% aquatic plant diet from the Animas above mainstem Cement Creek or below Mineral Creek. This finding suggests that muskrats or other herbivorous mammals are unlikely to be affected by the current conditions in the Animas River at the EUs evaluated in this BERA.

5.8 General risk conclusions for wildlife receptors

- **Animas River above mainstem Cement Creek**

Minimal potential risk to wildlife receptors is observed in this reach of the Animas River associated with Zn (American dipper, as a surrogate for the federally and state-listed southwestern willow flycatcher) and Pb (belted kingfisher). It appears unlikely that this potential for risk is actionable because the geomean HQs barely exceed unity.

- **Animas River below mainstem Mineral Creek**

Cu is identified as a potential risk driver to the American dipper and the mallard at sampling locations A73B and A75B. This risk is driven by estimated benthic tissue levels because no benthic invertebrates were collected from these two sampling locations for residue analysis. The other three major COPECs are not of concern to any of the wildlife receptor groups in this reach of the Animas River.

The increased risk of Cu in the American dipper versus the mallard is driven almost entirely by the higher food ingestion rate of the former species compared to the latter (0.0519 kg/kg/BW-day, dw, versus 0.2173 kg/kg BW-day, dw which results in a ratio of 4.2). This difference is because the average adult American dipper weighs 0.0565 kg and the average adult mallard weighs 1.162 kg (see **Table 4.29**). As such, the American dipper appears to be a suitably sensitive wildlife receptor for future risk evaluations on this river system.

5.9 Uncertainty Analysis

Uncertainty is inherent in any ecological risk assessment due to incomplete or inadequate knowledge about a number of key input parameters. This lack of knowledge is usually addressed by making exposure and toxicity estimates using the limited available data, or by making conservative assumptions based on guidance and best professional judgment when no reliable data are available. The major uncertainties associated with this BERA are discussed below.

5.9.1 Community-level receptors

- It is unclear if mainstem Cement Creek or Mineral Creek upstream of the confluence with South Fork Mineral Creek supported aquatic life before mining activities started in their watersheds in the 19th century (Church *et al*., 2007). If this observation is correct, then any impairment may not reflect negatively on current conditions in those two waterways. This situation represents a serious uncertainty, which would have to be considered as part of any future risk management decision-making.

- Except for Al and Fe, the surface water exposures evaluated in this BERA are based on dissolved metal concentrations, which represent the toxicologically "active" fraction of the total metals. Basing the surface water exposures on this fraction is not overly conservative and does not generate much uncertainty.

- Twenty sediment samples were collected from the reach of the Animas River above mainstem Cement Creek between A60 and A68. The data from these samples were pooled into a single, large dataset representative of that EU. The sediment datasets collected from the EUs on the Animas River below mainstem Mineral Creek were uniformly small (n = 3 to 5) which was not always enough to calculate representative EPCs using ProUCL. Hence, some uncertainty is associated with the risk conclusions derived from these smaller sediment datasets.

- Risk to community-level receptors was assessed using the HQ method. The HQs were not summed to calculate a Hazard Index (HI), because a HI assumes that HQs are additive. It is not anticipated that all of the inorganic COPECs evaluated in this BERA would exert their toxic effects on one and the same organ, which is a basic requirement for calculating HIs. On the other hand, it is possible that some of the COPECs may in fact exert additive

toxicity, in which case the HQ approach would underestimate certain risks. This observation applies equally to the wildlife evaluation.

- Be and Ag in surface water were retained as COPECs for community-level aquatic receptors even though these two analytes are not present above their DL in most of the EUs. The HQs represent half of the highest DL divided by the chronic benchmark. The HQ exceedances are particularly striking for Ag (see **Tables 3.5, 3.6, and 3.8**). It is not known if Be and Ag represent a realistic but unquantifiable concern for this BERA. This lack of information represents an uncertainty, which may need to be addressed as part of the risk management process.

- Only one benthic species (the amphipod *H. azteca*) was used for the sediment toxicity tests. Even though this species is considered sensitive to contamination, it is not known how much more or less sensitive it is compared to the benthic invertebrate species typically found in the Animas River upstream and downstream of Silverton (particularly the EPT species). At a minimum, the fact that the toxicity endpoints responded significantly at all sampling locations in the ten-day sediment toxicity test compared to the laboratory sediment control sample shows that the test organisms were sensitive to the chemical conditions found in the field-collected sediment samples. As a result, the uncertainty about species sensitivity is small.

- Juvenile rainbow trout were used in the surface water toxicity tests. This species is directly relevant to the fish populations found in the Animas River. Rainbow trout (and particularly juvenile life stages) are considered quite sensitive to the presence of metals in surface water. Hence, the uncertainty associated with their response to the acute exposures in the laboratory is minimal. However, the test did not assess toxicity from chronic exposures typically experienced by fish populations in the Animas River. The lack of an acute response in juvenile rainbow trout at sampling locations A73, A73B, A75B, and BBridge does not imply that a toxic response would not be present under longer-term exposures in the laboratory. This data gap would have represented a large uncertainty by itself, but is negated by the results of the 2010 and 2014 fisheries surveys performed by the CDOW that show sharp declines or complete extirpation of trout populations in the Animas River below mainstem Mineral Creek. These findings were further supported by the MiniSipper data that show the presence of multi-week chronic toxicity for several metals in surface water before and during the snowmelt period. As a result of these two supporting lines of evidence, the uncertainty associated with the lack of chronic toxicity to juvenile rainbow trout exposed to surface water samples collected from the lower reaches of the Animas River is considered minimal.

- All the trout species in the Animas River bury their eggs in gravelly substrate during spawning. These eggs remain in the gravel for several months until they hatch. The sac fry stay in the substrate for several more weeks until they have resorbed their yolk sac, after which the juveniles emerge into the overlying surface water. Hence, for six plus

months the embryo-larval stages of trout are fully exposed to metals in pore water (note: the surface water benchmarks are derived from toxicity tests on hatched fish, not eggs). This BERA used the pore water HQs only to assess the risk to the benthic invertebrate community. This particular assessment was not performed for the sac fry, however, because the other three lines of evidence already showed unacceptable risk to the fish community. Note that the risk from pore water exposure to trout sac fry is identical to the benthic invertebrates because both aquatic community-level receptor groups are evaluated using the same set of surface water screening benchmarks. Hence, the risk from pore water exposure to trout sac fry in the Animas River is provided in **Tables 5.13 to 5.18**.

- The benthic invertebrate risk derived from analytical chemistry data is based only on metal concentrations measured in sediment and pore water. The substrate of the Animas River and its two major tributaries in the area of Silverton consists mostly of gravel, cobble, and boulders. It is therefore reasonable to expect that the benthic invertebrates present on and within this substrate will also be exposed, at least in part, to metals present in the overlying surface water. The surface water exposure pathway was not explicitly evaluated for the benthic invertebrate community in this BERA, but would be a factor based on the risks to fish as determined from surface water chemistry data. This assessment was not performed, however, because the other four lines of evidence already show unacceptable risk to the benthic invertebrate community. Note that the risk from surface water exposure to benthic invertebrates is identical as that for fish because both aquatic community-level receptor groups are evaluated using the same set of surface water screening benchmarks. Hence, the risk of surface water exposure to the benthic invertebrate community is provided in **Tables 5.20 to 5.30**.

5.9.2 Wildlife receptors

- The exposure modeling used published Biota-to-Sediment Accumulation Factors (BSAFs) or regression equations, instead of field-collected tissue samples to estimate COPEC levels in fish and plants (and benthic invertebrates, but only at sampling location A73B and A75B from which tissue samples were not available). The evidence presented in this report strongly suggests that the literature-derived values for benthic invertebrates poorly predict Site-specific contaminant uptake and tissue levels, resulting in uncertainty. As a result, the risk from Cu to the American dipper and mallard at sampling locations A73B and A75B is considered hypothetical. Additionally, the soil-to-plant regression models and uptake factors were derived from terrestrial studies because no studies have been published to measure sediment-to-plant contaminant uptake. It is not known if or how metal uptake in plants differs between soil and sediment, resulting in uncertainty about actual risk to the omnivorous birds and the herbivorous mammals feeding on aquatic plants.

- Benthic invertebrates were collected for residue analysis in September 2014. These samples provide measured (versus estimated) tissue data for use in the food chain models for the American dipper and the mallard. It is not known how much or if metal levels fluctuate in benthic tissue throughout the year or across years in the Animas River. Also, with only a single sample to work from, the RME and CTE concentrations derived from the benthic invertebrate samples for use in the EDD calculations are identical to each other. The small benthic invertebrate tissue residue dataset represents an uncertainty but it appears unlikely that additional benthic residue sampling events in the future would greatly change the current wildlife risks.

- The exposure modeling assumes that the Animas River reach above mainstem Cement Creek between sampling location A60 and A68 equals a wildlife receptor's entire home range and forage range (i.e., area use factor = 1.0). This assumption is not unrealistic, given that this reach covers about two miles of river habitat, and therefore has limited uncertainty.

- Forty surface water samples were collected from the reach of the Animas River above mainstem Cement Creek. Twenty five of those samples were collected at sampling location A68. But even though this data set is assumed to represent the entire EU, it focuses on one specific location. The impact on the risk conclusions, however, is expected to be minimal. A review of the surface water chemistry data obtained from the six sampling location in this EU shows that the metal concentrations are quite similar to each other. As such, it appears unlikely that the current surface water dataset for the Animas River above mainstem Cement Creek generated unrepresentative EPCs.

- The exposure modeling included sediment ingestion. The substrate composition of the Animas River at and below Silverton appears to include large fractions of coarse sand, gravel, pebble, and small cobble, instead of the fine sands and silts expected to be accidentally ingested by wildlife receptors during feeding. The actual incidental sediment ingestion may be substantially lower than assumed in the food chain models, which would slightly decrease the calculated HQs.

- The characterization of exposure assumes that enough aquatic invertebrates, fish, and aquatic plants are present in the two Animas River reaches to feed the four wildlife receptor populations evaluated in this BERA. This assumption is speculative in light of the presence of aquatic toxicity to fish and benthic invertebrates identified in the surface water and sediment. Instead, the evidence shows that these two receptor groups are impacted and therefore may not be available in the quantities needed to support viable wildlife receptor populations as assumed in the food chain models. If so, then the estimated exposures, and the resulting risks to wildlife, may be more hypothetical than real.

- The COPEC tissue residues in fish were derived from the COPEC levels measured in sediment samples. This approach assumes that the entire mass of COPECs present in fish originates from the sediment. The relatively high levels of metals detected in Animas River surface water make it likely that fish also accumulated COPECs via bioconcentration through the gills. This additional pathway would have increased tissue residue levels but is not accounted for in the exposure modeling. Therefore it is possible that the EDDs for the belted kingfisher may have been somewhat underestimated.

- The effects assessment for the wildlife receptors used published no-effect and effect TRVs to measure COPEC toxicity. The assessment endpoints focus on preserving populations, whereas TRVs are derived from data on individuals of a test species. Extrapolating individual effects to higher levels of ecological organization is inherently uncertain, particularly because these extrapolations are applied across non-related species (e.g., chicken to belted king fisher, or mouse to muskrat). The degree of uncertainty with this approach is unknown.

- The wildlife TRVs apply to all birds or mammals. This means that the same COPEC-specific TRVs were used for the American dipper, mallard, and belted kingfisher. It is unknown how much more, or less, sensitive these three receptors species might be compared to the test species employed to generate the TRVs used in this BERA. Using "one-size-fits-all" TRVs creates much uncertainty about the actual toxicity of a COPEC to the target wildlife receptor. However, the TRV-derivation process is conservative by design, such that it appears more likely that the wildlife risks are overestimated rather than underestimated.

- The consistent use of conservative assumptions (such as assuming 100% of contaminant bioavailability in food items, assuming feeding in a habitat which may lack food items, relying on TRVs derived from toxicity tests using soluble or other highly bioavailable fractions of the test chemical, and using conservative "one size fits all" TRVs) most likely overestimated risk to the wildlife receptors evaluated in this BERA. As a result, the actual risk to wildlife receptors may be substantially lower than reported.

6.0 SUMMARY AND CONCLUSIONS

6.1 Introduction

The Animas River flows through the town of Silverton in San Juan County, CO. This waterway is affected by water, which has come in contact with mineralized material, either naturally or as a result of mining activities, such as through the creation of mine adits. The affected water originates in the upper reaches of two major tributaries of the Animas River in this area, namely Cement Creek and Mineral Creek, and from other tributaries of the Animas River further upstream of Silverton. Some of the tributaries contain high levels of metals and acidity that are carried downstream to the Animas River. This evaluation did not attempt to separate natural contamination from past mining-related contamination, but assessed the total risk from all sources combined.

The surface water data represente dozens of samples collected from all the EUs between May 2009 and September 2014. The sediment data set was substantially smaller and consisted of analytical data collected from those same waterways during five sampling events between May 2012 and September 2014. The pore water data set represented two sampling events on the Animas River and mainstem Mineral Creek in April 2014 and September 2014. The benthic invertebrate tissue data set came from one sample-collection event in September 2014. The data were reviewed to identify assessment endpoints and measures of effect, and to develop a CSM, which showed the movement of contaminants from the sources to the receptors.

The effects evaluation used chronic surface water benchmarks (hardness-adjusted, if necessary) for the surface water and pore water samples, plus no-effect and effect sediment benchmarks, to quantify risk to benthic invertebrates and fish exposed to surface water, pore water and sediment. No-effect and effect TRVs for birds and mammals were used to assess the toxicity of metals taken up via ingestion by wildlife receptors. Additionally, surface water and sediment toxicity tests were performed in the laboratory on samples collected from mainstem Cement Creek, mainstem Mineral Creek, and the Animas River above Cement Creek and below Mineral Creek to measure effects to benthic invertebrates (the amphipod *H. azteca*) and juvenile rainbow trout (*O. mykiss*).

Mainstem Cement Creek, mainstem Mineral Creek, and the three reaches of the Animas River were treated as separate EUs to derive RME and CTE EPCs for use in the baseline evaluation. To fine tune the exposure to aquatic community-level receptors, the surface water data were further split into three hydrologic periods, namely the pre-runoff period (February to April), runoff period (May and June), and the post-runoff period (July to November).

The EPC calculation method varied depending on the EUs, as follows:

- *Animas River above mainstem Cement Creek*: the surface water, sediment, and pore water analytical data were combined into three separate datasets to calculate COPEC-specific RME and CTE EPCs across the sampling locations.

- *Animas River between Cement and Mineral Creeks*: only two surface water analytical data were available from the two sampling locations in this reach of the river. Therefore wildlife receptors were not evaluated because sediment analytical data were required to estimate the tissue residue levels in the food items evaluated in the food chain models. The surface water analytical data were summarized by sampling location for calculating COPEC-specific RME and CTE EPCs to evaluate the fish and benthic invertebrate community.

- *Animas River below mainstem Mineral Creek*: up to several miles separate the various EUs in this lower reach of the river. As a result, this BERA assumed that wildlife receptors would not be exposed across the entire reach. Instead, the surface water, sediment, and pore water analytical data were summarized by sampling location to calculate COPEC-specific RME and CTE EPCs for use in food chain modeling and to assess exposure to the benthic invertebrate and the fish community.

- *Mainstem Cement Creek*: this BERA did not evaluate wildlife receptors foraging in this EU because the SLERA showed that current chemical conditions in this waterway are too degraded to provide forage for wildlife. The surface water and sediment data from the two sampling locations at the mouth of the creek were used to calculate COPEC-specific RME and CTE EPCs to evaluate risk to the fish and benthic invertebrate community.

- *Mainstem Mineral Creek*: this BERA did not evaluate wildlife receptors foraging in this EU because current chemical conditions in this waterway are too degraded to provide enough forage for wildlife. The surface water and sediment data from the sampling location at the mouth of the creek were used to calculate COPEC-specific RME and CTE EPCs to evaluate risk to the fish and benthic invertebrate community.

Exposure to the four wildlife receptor species foraging in the reaches of the Animas River above mainstem Cement Creek and below mainstem Mineral Creek was quantified using a food chain model which calculated RME and CTE EDDs based on ingesting surface water, sediment, and food items. The food items consisted of benthic invertebrates, fish, and aquatic plants, depending on the target wildlife species. The contaminant levels in the benthic invertebrates were based on measured values (except at sampling locations A73B and A75B), whereas the contaminant levels in fish and plants were estimated by multiplying the sediment RME and CTE COPEC levels by published COPEC-specific sediment-to-biota accumulation factors or by using published regression equations.

Risk was quantified using the HQ method, which compares measured exposures (i.e., RME and CTE surface water, sediment, and pore water EPCs) or estimated exposures (RME and CTE wildlife EDDs) to chronic surface water benchmarks, and no-effect and effect sediment benchmarks and wildlife TRVs.

A COPEC-specific HQ was then calculated using the following general equation:

$$HQ = EPC \text{ or } EDD/\text{benchmark or } TRV$$

Where:

HQ	=	Hazard Quotient (unitless)
EPC	=	RME and CTE Exposure Point Concentration (µg/L or mg/Kg)
EDD	=	RME and CTE Estimated Daily Dose (mg/kg bw-day)
Benchmark	=	chronic surface water benchmarks or sediment no effect and effect benchmarks (µg/L or mg/kg, respectively)
TRV	=	no effect and effect wildlife Toxicity Reference Value (mg/Kg bw-day)

HQs equal to or above one identified a potential for ecological risk, whereas HQs below one were used to eliminate chemicals with assurance that they did not pose a risk.

Besides assessing the potential impacts associated with RME and CTE exposures, the risk characterization for fish and benthic invertebrates also viewed each surface water and sediment sample as an individual exposure event in time. HQs were calculated for all available surface water and sediment samples and were used to form "scatter plots" by sampling station and hydrologic period (i.e., pre-runoff, runoff, and post-runoff). Those plots were then used to identify patterns of risk across the waterways and hydrologic periods.

Finally, toxicity data from benthic invertebrates and fish exposed to surface water and sediment in the laboratory were evaluated statistically to determine which of the observed responses were significantly different from laboratory control samples. Benthic community data collected in September 2014 were graphically analyzed and compared to historic data collected from the same sampling locations in the past. Data from past fish surveys were also reviewed

Uncertainty was inherent in this BERA because many assumptions were made in order to proceed with the investigation. These assumptions affected all aspects of the assessment including the CSM, the effects analysis, the exposure analysis, and the risk characterization. The uncertainty analysis identified and discussed the major assumptions made in this BERA. It also provided a short description to determine if the assumptions were likely to have overestimated or underestimated the potential for ecological risk. The end result was a balanced overview of uncertainty to help risk managers understand the full extent of potential ecological risk to

receptors living or feeding in mainstem Cement Creek, mainstem Mineral Creek, and the Animas River at and below Silverton.

6.2 Risk conclusions for benthic invertebrates

Taken together, the four independent measurement endpoints (i.e., comparison of bulk sediment chemistry to sediment benchmarks, comparison of field-collected pore water chemistry to surface water benchmarks, sediment toxicity tests, and recent plus past benthic community survey results) show a strong potential for risk to the benthic invertebrate community in various sections of the Animas River, as well as in mainstem Cement and Mineral creeks.

The sediment HQ evaluation and sediment toxicity test results do not provide a consistent picture. The sediment HQ analysis identifies sediment samples CC49 and M34 as the least impacted by metals, whereas sediment samples A75B, BBridge, and the Animas River upstream of Cement Creek are the most impacted by metals. This pattern is contrary to the outcome of the sediment toxicity test, which shows the highest toxicity at CC49 and M34 and lower (relative) toxicity in the Animas River above mainstem Cement Creek, plus A75B and BBridge.

6.3 Risk conclusions for fish

- **Mainstem Cement Creek:**

The chemical conditions in surface water from mainstem Cement Creek were highly toxic to fish, particularly due to low pH and high Al, and to a lesser extent by the presence of Cd, Cu, and Zn. The toxicity tests showed that surface water collected from this EU in November 2012 (i.e., post-runoff period) was acutely toxic to juvenile rainbow trout. The preponderance of evidence suggested that the fish community in mainstem Cement Creek (if present) would experience lethal stress under current conditions.

- **Mainstem Mineral Creek:**

The chemical conditions in surface water from mainstem Mineral Creek appeared less severe than in mainstem Cement Creek for the local fish community. However, serious pH drops during the pre-runoff period coupled with high Al levels during the pre-runoff and post-runoff periods suggested that fish may experience high stress in the winter, summer, and fall, but that survivors could possibly recover during the rest of the year (spring). The toxicity tests showed surface water collected from this EU in November 2012 (i.e., post-runoff period) and April 2013 (pre-runoff period) was acutely toxic to juvenile rainbow trout. The preponderance of evidence suggested that the fish community in mainstem Mineral Creek (if present) would likely experience high stress under current conditions.

- **Animas River above mainstem Cement Creek:**

The chemical conditions in surface water from this reach of the Animas River between A60 and A68 indicated the presence of one or more sources of metal contamination located further upstream in the watershed. The chemical signature of the surface water suggested that chronic toxicity to the fish community was possible, particularly due to the presence of Al, Cd, and Zn. Low pH, on the other hand, was not an issue in this reach. The presence of significant acute toxicity measured in juvenile rainbow trout exposed to surface water from this reach further confirms the results of the chemical analyses. The preponderance of evidence suggested that the fish community in this reach of the Animas River is stressed during much of the year. This conclusion was supported by the fact that daily surface water samples collected between April and July 2014 using "MiniSipper" sampling devices positioned at location A56 (upstream of A60) showed the presence of potentially severe chronic toxicity associated with dissolved Al, Cd, Cu, Pb, and Zn during the pre-runoff and runoff periods.

- **Animas River between mainstem Cement Creek and mainstem Mineral Creek**

Little chemical information on the quality of the surface water was available because only two samples were collected and no acute toxicity testing was performed. The limited amount of data suggested that this reach of the Animas River was likely to be lethal to fish, mostly due to low pH and high levels of aluminum, with secondary stress caused by Cd and Zn.

- **Animas River below mainstem Mineral Creek**

The chemical signature of the surface water in this reach of the Animas River reflected the major inputs from mainstem Mineral and Cement Creek, and the reach of the Animas River above mainstem Cement Creek. Surface water samples collected from sampling location A72 during the pre and post-runoff periods were acutely toxic to juvenile rainbow trout. Surface water samples collected during the same two hydrologic periods from the EUs further downstream did not show acute toxicity, suggesting that the effect had been "diluted out". However, the preponderance of evidence shows that Al, Cd, and Zn in surface water may exert chronic effects on the fish community to at least the Bakers Bridge EU located about 30 miles downstream from Silverton. This conclusion was supported by two additional lines of evidence:

- Daily surface water samples collected between April and July 2014 using "MiniSipper" sampling devices positioned at locations A73, A75D and BBridge showed the presence of low-grade but multi-week chronic toxicity associated with dissolved Al, Cd, and Zn during the pre-runoff and runoff periods.

- A fisheries survey performed by the Colorado Division of Wildlife (CDOW) in 2010 on the Animas River in the vicinity of sampling locations A72, A73, and A75D/A75B showed a severe decline of the trout populations at all three locations between 2005 and 2010. The CDOW ascribed this collapse to a drastic reduction in surface water quality apparently associated with the discontinuance of a water treatment project in the Gladstone area on Cement Creek upgradient from Silverton. A 2014 follow-up fisheries

survey by the CDOW in the vicinity of sampling location A75D/A75B showed that the trout population had continued to decline to very low numbers.

6.4 Risk conclusions for wildlife receptors

- **Animas River above mainstem Cement Creek**

A potential for minimal risk to wildlife receptors was identified for Zn (American dipper) and Pb (belted kingfisher). The American dipper was also used as a surrogate species to perform a conservative assessment of risk to the southwestern willow flycatcher, a federally and state-listed bird species. The evidence did not suggest that this species was at substantial risk from foraging in the Animas River above mainstem Cement Creek between sampling location A60 and A68.

- **Animas River below mainstem Mineral Creek**

The potential for risk to wildlife receptors in this reach of the Animas River was restricted to Cu in the American dipper at sampling locations A73B and A75B, with minor risk from Cu to the mallard (100% diet only) at the same two locations. The remaining COPECs were of no concern to any of the wildlife receptors. Benthic invertebrates were not collected for tissue residue analysis from sampling locations A73B and A75B. Instead, the levels of metals in benthic tissues at these two locations were estimated using conservative published sediment-to-benthic invertebrate regression models and uptake factors for use in the food chain model. It is noteworthy that the only two sampling locations with excessive risk from Cu were A73B and A75B. Given this pattern, it was concluded that the risk from Cu was hypothetical and unlikely to be realized in the field.

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